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A Study of Innovation Networks Management in the Rail Industry:

A case study of the Overseas Technical Certification Process in the Korean Rail Industry

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Preface

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text. I further state that no substantial part of my thesis has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. It does not exceed the prescribed word limit for the relevant Degree Committee.

Jeeyeon Choi
St Edmund's College
August 2020

Abstract

A Study of Innovation Networks Management in the Rail Industry: a case study of the Overseas Technical Certification Process in the Korean Rail Industry

Jeeyeon Choi

The project of supporting standard certification acquisition is part of the activities for sustainable growth. In many countries, the market for technology certificate tests is gradually expanding in its role and size. Therefore, many countries have been working on policies and activities to support their testing and certification institutions. This study explores ways to effectively support technology certification tests by developing and applying efficient networks and communication systems and management of technical tests of SMEs in Korea. Additionally, this study also seeks ways of strengthening the competitiveness of the international certification markets by establishing and developing a system for capacity building the Korean certification industry. To do this, I studied overseas technical certification test cases of a Korean SME.

Throughout this literature review, I identify the importance of the network and the opinions of various scholars on the communication and knowledge transfer needed for the use of networks. Moreover, I explore various theories on the transfer of technical knowledge and the active use of users and the MLP framework that would enable network description. I also found that despite the importance of the technology certification industry, there is a limitation on the research of this area. Therefore, by studying the Korean Testing Laboratory test cases, a part of the insufficient research could be filled.

Each test is conducted through technical testing agencies in France and Germany to determine what level a company's technology has reached against the European technical standards. For this purpose, the network between the related organisations is analysed based on the Multi-Level Perspective Framework. Then the activities of the Korean Testing Laboratory for communication, technical knowledge and information exchange are analysed. The establishment and use of communication and knowledge exchange systems used during the test processes are studied to carry this out.

In a technical certification test, the study finds that a collaborative network of various participants acts at the regime-level across almost all areas, such as science, technology, culture, politics, society and economic markets; this is novel and very important in practice. Furthermore, it can be confirmed that communication and knowledge exchange activities, organisational culture and capability of the organisation play a more significant role than external environmental factors. By confirming this, the

study aims to shed light on the Korean Testing Laboratory’s role and its importance as the leading participant in the technology certification industry, both domestically and internationally.

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This journey has been challenging, exciting and rewarding for me. I have been lucky to have many people helping and supporting me throughout this journey. I dedicate this thesis to all of the people who have been with me on my journey.

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List of Abbreviations

ANT	Actor-Network Theory
AsBo	Assessment Body
BMS	Business Management Systems
CCPSA	Canada Consumer Product Safety Act
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Electrotechnique
CRADA	Cooperative R&D Agreement
CTA	Constructive Technology Assessment
DB	Deutsche Bahn
DeBo	Designated Body
EN	European Norm
EU	European Union
ERA	European Railway Administration
ERRAC	European Rail Research Advisory Council
ESO	European Standardisation Organisations
ETSI	European Telecommunications Standards Institute
IRIS	International Railway Industry Standard
IRS	International Railway Solution
ISO	International Organization for Standardisation
KIP	Korea Institute of Procurement
KTL	Korea Testing Laboratory
KOTI	Korea Transport Institute
KOTRA	Korea Trade-Investment Promotion Agency
LTS	Large-scale Technology Systems
MLP	Multi-Level Perspective
MOLIT	Ministry of Land, Infrastructure, and Transport
NoBo	Notified Body
RATP	Autonomous Parisian Transportation Administration
R&D	Research and Development
SCOT	Social Construction of Technology
SNCF	The Société Nationale des Chemins de fer Français
TAM	Technology Acceptance Model
TBT	Technical Barriers to Trade
TSI	Technical Standards for Interoperability

UIC	International Union of Railways
UNIFE	Union des Industries Ferroviaires Européennes
WTO	World Trade Organisation

1. Introduction

1.1 Research Background

In many countries, the railway industry is an industry that can lead technology development, create employment and contribute to comprehensive national competitiveness as a national strategic infrastructure industry (KIP 2015). Therefore, it has been naturally recognised that governments or countries participate in the railway sector, because railways are national projects related to people's lives and welfare, as well as industries closely related to a country's economic and technological growth. As a result, many countries are making various efforts to advance the railway industry abroad as part of the creation of future growth engines, especially in the field of railway technology. Especially in South Korea, as the competition among foreign companies over the domestic railway and parts industry accelerates, domestic companies that are developing railway technology are starting to feel more and more threatened. In this regard, while strengthening the competitiveness of the railway parts industry, a lot of effort is being made to develop technologies to advance into overseas markets.

Overseas railway markets have already been dominated by advanced countries for a long time, so it has not been easy for domestic companies to advance into overseas markets due to a lack of technical skills, information, human network and experience (Moon. J. and Kim. D. 2011). In response, the Korean government has proposed many policies to revitalise the overseas railway project, including the Korea Testing Laboratory (KTL) project to support the acquisition of overseas standard certification. It is a project that is helping domestic railway component technology to be certified overseas and is being supported by the government. This project will be able to increase the possibility of overseas advancement of domestic technology and increase competitiveness by providing various overseas technical standards and testing opportunities that cannot be easily obtained by small and medium-sized enterprises alone. Moreover, by supporting testing, KTL has been carrying out this project domestically, in Korea, as well as abroad for a long time.

However, Korea's SMEs, which aim to develop and commercialise technology products, have difficulties in obtaining enough information, even though they have government support, including certification tests. This was mainly due to the SMEs' lack of a clear understanding of licensing, such as the technical regulations and certifications, and their lack of in-depth understanding of the role of related agencies, as well as the government's use of inefficient certification systems (Innothink 2016). Moreover, in many cases, renowned overseas testing institutions tend to be preferred over domestic testing agencies, and the additional costs issued are also included in the difficulties faced by small and medium-sized enterprises. Based on this given background, KTL has years of experience in communication and knowledge exchange. It is for supporting domestic and overseas technology development projects of Korean SMEs. Also, KTL has been trying to build networks with national and international testing institutions with the aim of helping local Korean technology development companies. To this end, the KTL has always worked with the government, and with small and medium-sized technology development companies in Korea, and various government-affiliated organisations involved in technology testing and certification. To ensure the representativeness of overseas technical tests KTL has formed and cooperated with various institutions as followings: the Korean government, a Korean SME (Shangshin Brake), overseas testing agencies (SNCF-AEF, DB), overseas certification organisations (UNIFE and UIC), an overseas test support organisation (Eurailtest), and a consultant who supports the overseas testing process on behalf of KTL.

Therefore, this study uses the case of KTL's overseas technical test support in connection to mutual understanding and efforts for communication and knowledge exchange systems and network development among various institutions. The changing network as a result of the actions of the relevant agencies and their interactions is very suitable to be described through the MLP model (Geels 2006a). Moreover, there have not been many studies on communication and knowledge exchange networks in the technology certification testing industry of SMEs. Therefore, through this study, I want to provide some insight for KTL to develop effective networks and identify communication systems for the use of support for overseas technical certification tests. To do this, I investigate the activities of the actors involved in the tests by using the MLP, which is designed to facilitate research on how organisations at different levels create networks, how mainstreaming of technology is done, and they interact. It also can contribute to research that can help organisations to plan a way forward which enables them to develop networks and communication systems related to domestic and foreign technology certification tests.

1.2 Research Objectives

This study aims to investigate the technology developments and transitions of the Korean railway industry. This study aims to enhance our understanding of the importance of technology developments and transitions in the railway industry for enhancing competitiveness in the global world. The research will take the Korea Technology Laboratory (KTL) as its case study and will use the Multi-Level Perspective (MLP) as an analysis method.

Answers to the following questions are sought. The overall research question is:

How did KTL influence railway technology developments through collaboration with overseas agencies?

The sub-questions are:

- What role has KTL been playing in technological innovation in the Korean railway industry?

- What role does KTL play in advancing Korea Railroad technology into overseas markets?

The objectives of this research are:

- To enrich our understanding of the technological development pathway of the railway industry.
- To provide insights into the mechanisms through which different actors can play roles in railway technology development.
- To understand the role of KTL in the technology development of the Korean railway industry.
- To investigate the process of technology testing overseas through real testing cases.
- To understand the position of KTL as one of the important actors in the Korean railway industry in terms of technology development.

1.3 Research process and structure

This thesis consists of 7 chapters as shown in Figure 1. The following is a brief overview of each chapter.

Chapter 2: A Literature Review

In this chapter, I considered communication and knowledge exchange, the main concepts to be addressed in the paper, as one of the innovation processes, and looked at the studies related to basic knowledge about it. The content consists of the Technology and Innovation Process, Knowledge and Learning Process, and Technology Transfer. In addition, the Multi-level Perspective Framework was introduced based on the network survey of the various institutions included in the case study.

Chapter 3: Research Methodology

In this chapter, the purpose of the study and the research questions are identified, and the background is explained. The methods of data investigation and analysis are also introduced.

Chapter 4: A Preliminary Study

The purpose of this chapter is to explain the knowledge related to the railway industry. As the field of the case study is set in the railway industry, it briefly introduced the history of railway industry development in Europe and South Korea, and explained the reasons why technology development and development are important in the railway industry and national support. Furthermore, the technical certification system, which is a case study material, and the parts related to the testing process are introduced in more detail.

Chapter 5: Case Studies

A case study is examined to find answers to research questions using KTL's two recent cases supporting overseas certification tests of Korean company technology. Prior to explaining the test, KTL, a European technology certification system and research institute, is introduced. Subsequently, the details of the case studies on the European railway technology certification tests conducted in 2018 and 2019 are presented.

Chapter 6: Findings and Analysis

In this chapter, the case studies in Chapter 5 are linked to research questions in more detail, focusing on findings and their analysis. The actions, problems, and solutions that occurred during the test process are analysed in relation to the communication system and knowledge exchange system. Besides, the MLP framework is used to analyse the activities of institutions based on their roles in cooperative networks.

Chapter 7: Conclusion and Discussion

In the last chapter, the contents of the test and its impact are summarised, a review against the research questions is offered and contribution to knowledge is stated.

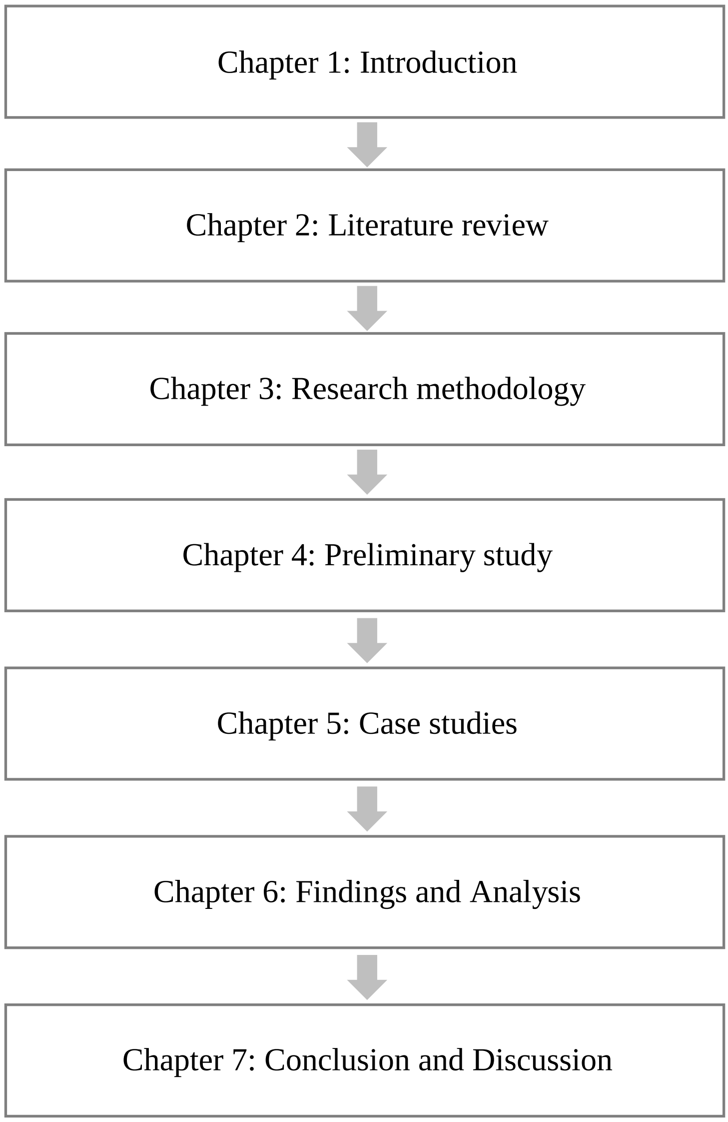

Figure 1 Thesis structure overview

2. Literature Review

This chapter investigates existing literature regarding technology transitions in industry developments and the Multi-level Perspective framework which will be used for analysis. This chapter starts with the nature of the industrial transition. Then, the theoretical background will be explored. Studying industrial transitions of technology in railway industries will enhance the understanding of transition mechanics. Also, in this chapter, the MLP framework will be explored.

This study aims to explain the development of railway technology and the transition process of technology through the use of a case study. Therefore, it is necessary to understand the process of communicating, accepting, learning and transferring knowledge in various relationships within internal and external organisations' networks that relate to innovation in technology. To do this, I began by studying the preceding literature related to the railroad industry technology and the MLP which is to be used as a research method.

2.1 Innovation and Innovation process

In terms of its process, innovation has different processes according to the firms' aims, related fields, business environments, and the markets' characteristics with which they are faced. According to Mowery and Rosenberg (1979), the innovation process is about finding an opportunity to use new and developed products and services based on technological know-how or changes in markets' demands. It also includes a learning process through experiments and theories. Among the innovation processes, there is an innovation process in technology and it is tightly related to this study. The concept of technological innovation is widely used after Schumpeter mentioned the term 'creative disruption in his work (Schumpeter 2013). According to Schumpeter (2013), the development of capitalism is driven by firms' innovative activities, and firms have earned profits in return for the results of these innovations. At this time, the driving forces of innovation can be made from new combinations of innovative activities which include accepting new processes, exploring new markets, acquiring new resources, developing new management methods and new products/services.

Pavitt (2005) explains the technological innovation process as consisting of three parts which are creating science and technological knowledge, transforming knowledge into products (artefacts), and responding to market demands and sharing impact. Here, creating science and technological knowledge starts from an understanding of the changes in environments, such as specialisation of sectors, functions and institutions, by studying history and society. Transforming knowledge into products refers to the process of profit-making by using knowledge that is supportive of complex and advanced technologies. Also, responding to market demands and sharing impact is the process in which technologies evolve with competitive markets, and this includes the continuous efforts to meet the consumers' demands. Amongst these, in particular, the benefits from specialisation is stressed by Adam Smith; he insists that specialisation has made invention and innovation processes more effective (Smith 1937). Moreover, the increase of specialisation enables the greater complexities in new services and products, as well as allowing firms to have economic benefits such as reducing technological costs (Pavitt 2005).

2.2 Networks and innovation process

In many studies, the networks of firms have been researched with firms' competitiveness in the markets in mind. According to Chesnais (1991), national competitiveness in the long-term depends on the collaboration and interaction between firms that were made for developing the dispersion of technologies. Also, Best (1990) explains that new global competitiveness depends on innovative performances by using networks between companies. In innovation processes, networks emerge to solve the increasing specialisation and complexity. The emergence of innovative technologies has led to a complex of new products and services, therefore, to deal with these complex products and services, the integration of various specialised technologies have been needed (Best 1990). As an organisational solution to achieve this problem, networks are now considered more important than before (Küppers and Pyka 2002).

Many studies explain that the capability of organising relationships between organisations in networks is one of the key factors. Regarding the elaborate case-study of the strategic collaboration in the Japanese car industry, Rycroft and Kash (2004) said that the interaction of the firms which made a network increased the firms' learning abilities. According to the 'Confederation of British Industry', companies actively seek collaboration with other companies and universities not only to increase knowledge acquisition but also to reduce risks in innovation processes (DTI 1993). Chipika and Wilson (2006) study the importance of networks between companies and supporting institutions for improving products and designing new products. Through researching the advanced technology industry of Taiwan, Hsu (2005) confirms that the development of innovation networks to integrate research centres, governments, universities, industries, and international organisations was a huge influence on the development of the industry. Furthermore, Calia, Guerrini et al. (2007) confirm that the technological innovation networks provide not only the technologies for making competitive products but also the necessary resources for the restructuring of business plans of firms.

Networks depend on form and purpose. In a study on collaborative networks and technological innovations in the chemical industry, Ahuja (2000) divides networks into direct and indirect networks depending on their relationships. He found that these two relationships play very different roles: direct relationships are suitable for exchanging resources and knowledge, and indirect relationships are suitable for accessing specific information quickly. Chiffoleau (2005) studies networks by dividing them into two, the networks for building common knowledge and social identity, and the networks for collecting fast solutions to specific problems. Powell, Staw et al. (1990) divide the types of networks by duration and stability, specific purpose, relevance with existing networks, and degree of autonomy.

By focusing on time stability and types of governance, Grabher and Powell (2004) distinguish four main types of networks: 1) informal networks which based on shared experience, 2) project networks by short-term combinations to perform specific tasks, 3) local networks for maintaining communities with the help of spatial preferences, and 4) business networks as objective and strategic alliances between various parties. On the other hand, Granovetter (1977) offers different classifications: 1) primordial networks which are characterised by a common social identity, continued participation and close ties, 2) supply chain networks which are characterised by involvement in common projects, such as supply chains and large-scale construction projects, 3) invisible networks which are characterised by shared experiences and common interests, such as industry-academic collaboration centres, and 4) strategic networks which are purpose-oriented and the most important type. Moreover, among many studies of networks in terms of organisational structure, according to Ahuja, Lampert et al. (2008), the influences of inter-organisational networks have been increasing in innovative performances.

Networks are important for various reasons. For a long time, the collaboration network has been a key player in a variety of production processes, including the craft industry (Eccles 1981) and the industrial district (Brusco 1982, Piore and Sabel 1984). As knowledge creation is one of the key factors for enhancing firms' competitiveness level, the development of the knowledge-intensive industry increase the importance of networks from product development, distribution, research and development processes (Powell and Grodal 2005). In these fast-growing fields, various cooperation of firms enable companies to learn to widen knowledge, so that companies can be exposed to more experience, diverse capabilities and opportunities as their networks getting bigger (Beckman and Haunschild 2002). Also, as many different points of view become integrated, the chance to amplify opinions, which can create alternative or new solutions through discussion and discourse, increases (Powell and Grodal 2005).

According to Freeman (1991) and Hagedoorn (1995), the number of strategic alliances and the intensity of their alliances influences internal R&D intensity and technological sophistication. Powell and Grodal (2005) suggest that deepening network relationships can lead to greater commitment and more thorough knowledge sharing. Powell (1998) argues that organisations with diverse and multi-perspective ties to other organisations are likely to develop better codes of conduct for information exchange or dispute resolution. Powell and Grodal (2005)'s study shows that if organisations developed a broader capacity for interaction, they would be able to communicate complex knowledge better. Besides, with the use of networks, companies can broaden the resources and infrastructure knowledge available to them, attract new entrants who will benefit them, and develop broad cooperation (Powell and Grodal 2005). Also, Powell, White et al. (2005) confirm that having a strong network is important to the success or survival of an organisation.

There are many things that companies expect from building and operating networks. Many scholars agree that the use of networks increases the resources and knowledge which are needed for enabling innovation. This can also be confirmed by Powell, Koput et al. (1996), who argue that companies use outside networks to take a better position in the field of technology that is rapidly developing. Vinding (2002) stresses that the impact on innovation is significantly related to the type of network and the cooperative relationship, as emphasised by the benefits from strong regional ties. Godoe (2000) says radical innovation is more likely to arise from intimate and long-term interactions, while Powell, Koput et al. (1996) explain that, in terms of patents, the most important connection is research and development partnership, and the diversity of network links also gives positive influences on patent rates. Moreover, Ahuja (2000) notes that both direct and indirect networks have a positive effect on innovation. Van Wijk, van den Bosch et al. (2003) argue that the ability to communicate tacit knowledge is an important advantage of a close network. Also, Hansen (1999) mentions that complex knowledge is most easily communicated and transferred through a dense network. According to Powell and Grodal (2005), the relationship between network and innovation is cyclical, with external links promoting organisational growth and strengthening more innovation. All of these studies show that the majority of firms are focused on obtaining the necessary sources and knowledge for innovation over the network.

2.3 Knowledge and innovation process

At the same time, we need to consider knowledge. It is because learning and delivering knowledge is essential for communication which is needed in network operations for innovation effectively. So, the study of the definitions of knowledge and knowledge management, the role and importance of knowledge, forms and types of knowledge is needed, based on previous researches.

Knowledge management in innovation is both the most basic and the most important part. As the importance of the activities, such as especially talented people, gather to stimulate each other, share knowledge, skills, and experience, and be affected by each other, have been widely recognised. In particular, according to Malerba (2004), at the corporate level, knowledge is unique for each company, and not all companies have the same knowledge. Knowledge is not spread freely and automatically among companies, so it is characterised by the need for companies to adjust and absorb through accumulated learning over time (Malerba 2004). Also, most companies have different degrees of access to knowledge, and they have the opportunity to gain knowledge internally or externally, and when knowledge is encountered through an internal effect, it is related to acquire and emulate knowledge about new products or processes, while when knowledge is approached by external influences, it is related to the opportunity to obtain advanced science and technology (Malerba and Orsenigo 2000).

However, in knowledge management, understanding and identifying the forms and types of knowledge are necessary. First, from the perspective of knowledge management, the most common types of knowledge are explicit knowledge and tacit knowledge. Explicit knowledge is codified knowledge and it is also called know-what (Brown and Duguid 1998). These kinds of knowledge are easily identified and searches also can be stored (Wellman 2009). On the other hand, tacit knowledge had been defined by Polanyi (1966). Brown and Duguid (1998) called it know-how which is knowledge-based on experience and it is hard to define intuitively. Such tacit knowledge can be understood in each circumstance, tend to depend on the individual, is difficult to transfer, and is deeply rooted in relationships (Nonaka 1994). Moreover, according to Wellman (2009), this tacit knowledge has been considered as the most valuable source for leading to breakthroughs for innovation in organisations.

Therefore, efforts to identify differences in learning and delivery of knowledge depend on the type of knowledge, and to devise various ways to manage it effectively have been made by many scholars constantly. In particular, in the globalised era, most companies faced a situation in which they had to further expand their knowledge resources, and along with the creation of knowledge, they also faced the challenge of effectively conveying the knowledge (Park, Vertinsky et al. 2015). According to Park, Vertinsky et al. (2015), few companies have all the information and know-how which are needed to deal with rapid and complex environmental changes effectively, as well as few companies create partnerships with other countries to obtain the necessary knowledge resources from them. These are becoming a challenge for companies. This is because, given the diverse and complex nature of related tasks and processes, effective knowledge transfer within and across organisations is not easy (Easterby-Smith, Lyles et al. 2008). Pérez-Nordtvedt, Kedia et al. (2008) explains that the transfer of knowledge from other countries is a big challenge because of all the differences which can exist between organisations. This knowledge transfer is a difficult and costly process in terms of time and effort (Argote, McEvily et al. 2003).

In particular, the management of knowledge in the field of innovation is very important. According to Pavitt (2005), innovation is inherently uncertain, so it must involve learning through experimentation or theory. He divides innovation into three processes and the first process in the production of scientific and technological knowledge. This is because scientific and technical knowledge has become increasingly specialised by fields, functions and institutions, and thus understanding and learning about it is becoming more important (Pavitt 2005). Smith (1937) insists on the importance of specialisation in producing knowledge and said that the production of knowledge due to specialised education, the establishment of laboratories and the improvement of experimental technology increases the efficiency of technological innovation. Also, the study related to the importance role of universities emerged such as long-term research and collaborating programs by universities and companies, as the biggest benefits that knowledge-based universities can offer to the industry (Pavitt 2005).

2.4 Communication and innovation process

With creating networks and managing knowledge, communication is important in technological innovation processes. More innovations are needed due to the technology development projects which are becoming increasingly complex as various parts of technology converge, with shorter life cycles and fast-changing markets with the advancement of technologies (Hong and Kim 1998). According to Hong and Kim (1998), while technology research and development activities have been active not only within the country but also by overseas cooperation, such activities face many difficulties in operations and management, such as challenges in knowledge transfer and communication between the relevant personnel, differences in performance methods, imbalance in the compensation system, lack of interest in work performance, or frequent turnover of high-level personnel of organisations. Besides, cultural and geographical differences may be included in the difficulties.

Related to communication, Ghoshal and Bartlett (1988) argue that the density of inter-management communication within and outside a company has the most important impact on a company's ability to perform various innovation tasks, demonstrating through organised research that the invigoration of communication within a company is correlated with the company's innovation activities, adoption and technology proliferation. According to their argument, companies that create relatively high numbers of innovations have relatively high internal communication density among managers, who have both formal and informal mechanisms to promote and strengthen internal communication between different departments. While less autonomous entities tend to adopt or accept innovation within themselves, relatively more autonomous individuals use these formal and informal mechanisms to create and spread many innovations at the same time. Thus, Ghoshal and Bartlett (1988) explain that their autonomy is an important factor in innovation creation and diffusion along with communication.

Besides, Rothwell (1992) saw cooperation between manufacturing and marketing within the company, i.e. the degree of network and communication, as an important factor enabling successful. Besides, Clark and Fujimoto (1991) emphasised this role of cooperation and communication through an integrated functional study of heavyweight project managers for Japanese automakers. Communication is even more important when the knowledge you want to convey is tacit. According to Asheim and Gertler (2009), commonalities shared based on experiences, collaboration or informal interaction, and communications promoted by a shared institutional environment, help to promote the transfer of tacit knowledge among people in networks. Also, Lundvall (2016) argues that the production of tacit knowledge is mainly through user-producer interaction and communication, which also leads to the creation of new knowledge that is beneficial to both users and producers and that neither side can operate on its own.

The distinction used implicitly is tacit knowledge and explicit knowledge (Foray, David et al. 2000). Tacit knowledge stems from Polanyi's (1956) argument that people know more often than they can express in words, while explicit knowledge has a highly organised form, such as blueprints, recipes, manuals, or in the form of training (Powell and Grodal 2005). Implicit knowledge lacks such systematic documentation (Nonaka and Takeuchi 1995). Valuable and productive knowledge often requires considerable effort to acquire and such knowledge has characteristics that frequently change in the course of acquisition and application. Therefore, it is complicated to obtain knowledge of complex production techniques in a fully accessible form to anyone. (Powell and Grodal 2005).

Many studies explain how easy explicit knowledge is to deliver compared to tacit knowledge. Simonin (1999) shows that the transfer of knowledge within an alliance is negatively influenced by both the nature of knowledge and the difference in organisational culture. Simonin observed that there was a difference in knowledge exchange depending on the length of time (Simonin 1999). Older alliances propose learning curves to reduce side effects from inexperience and knowledge complexity by developing common languages and sharing mental models among partners (Powell and Grodal 2005). Therefore, there is an opportunity to communicate subtle forms of information as the alliance period more effectively, and participants develop their understanding of the relationship, even more, partners develop wider bandwidth of communications, complex implicit knowledge can become clearer (Powell and Grodal 2005).

If knowledge acquisition is a factor that makes knowledge transfer difficult, the costs of transfer are proportional to the kind of knowledge transferred (Powell and Grodal 2005). That is since the knowledge transferred initially is widely distributed at low cost (Boisot 1998), it is unlikely that explicit knowledge will include a particular component that leads to innovation (Powell and Grodal 2005). Conversely, the degree of difficulty and the costs of delivery tends to be high if knowledge is very closely related to the surrounding environment (Hippel 1998) and includes a large implicit component. As a result, the expected effects and benefits of this information may be uncertain because the cost of obtaining the information may be greater than the value of the information, which makes it possible to argue that when knowledge involves an intermediate level of complexity, the benefits drive from transition may be greatest (Powell and Grodal 2005). There is a change in the cost of information delivery and it can be assumed that the maximum value can be obtained when new ideas are delivered without significant difficulty (Fagerberg, Mowery et al. 2005).

A productive transfer of knowledge is essential, therefore, and companies in each field develop relevant capabilities to help with the overall flow of information and resources in the network to enhance their capabilities (Powell and Grodal 2005, Balland, Belso-Martínez et al. 2016). Sørensen and Torfing (2017) explain that strengthening the exchange of knowledge increases the efficiency and effectiveness of service production. Moreover, the importance of developing networks by exchange and transferring knowledge have been confirmed by many scholars, for example, by Lorenzoni and Lipparini (1999), who explains the importance and usefulness of a network by showing in their study that company managers have increased responsiveness to market conditions by developing the networks of professional suppliers, with a focus on developing supply chain relationships. In addition, Nunes, Lopes et al. (2019) explain that companies that focus more on developing knowledge networks can increase opportunities to achieve higher levels of innovation, thereby improving economic performance. Furthermore, Takahashi, Indulska et al. (2018) confirm that, in the case of collaborative research projects, the development of innovative products can be achieved by successfully transferring the newly created knowledge to the company's internal business network, showing supporting arguments that knowledge transfer is essential and that companies use networks to develop their information and knowledge management capabilities.

2.5 Multi-Level Perspective Framework

The Multi-Level Perspective (MLP) Framework has been widely used to describe and analyse the changes and transitions of the socio-technical system in the relationships of actors at various levels. In this study, this framework will be used to describe the relationships and interactions of actors involved in case studies.

2.5.1 Background of the MLP Framework

Due to the emergence of various environmental issues that are becoming more serious around the world, social and industrial changes to more sustainable production and consumption processes have been required and opinions on how to induce them have been raised (Fuenfschilling and Truffer 2014). Most of all, areas such as water, energy or transportation face resource shortages, climate change and environmental degradation, which require more alternatives (Fuenfschilling and Truffer 2014). To this end, in recent years, the scientific community has evolved with the idea of implementing sustainable development (van den Bergh, Truffer et al. 2011, Markard, Raven et al. 2012). Studies have shown that this is a complex and intertwined long-term process that simultaneously affects actors, skills and institutions (Fuenfschilling and Truffer 2014). Based on the recognition of evolutionary economics, scientific and technological research, and social sciences, various approaches have been developed to analyse and conceptualise changes in terms of social and technological systems (Fuenfschilling and

Truffer 2014). The concept of systems evolves into a stable configuration that emphasises the interdependence and common development of physical and social structures such as policies, culture, technology and markets, and enables the realisation of social functions over time (Fuenfschilling and Truffer 2014).

One of the main approaches to describe and analyse this complex transition process is the Multi-Level Perspective (MLP) model (Geels 2004, Smith, Stirling et al. 2005, Geels and Schot 2007). This model allows the whole process of social technology transition to be analysed through three levels of activities: socio-technical regimes, technology niches and landscape (Fuenfschilling and Truffer 2014). In other words, the MLP framework considers technological change as an interactive process of the narrow level of niche, also the intermediate level of the socio-technical system which is inherent in the broad level of landscape (Geels, 2002, 2005b; Verbong and Geels, 2007). The MLP explains technological transition through the interaction of processes at the three different levels, and according to Geels (2010), the main idea of the MLP framework is to explain innovations more systematically by looking for the relations and interactions between related actors in different processes: therefore the MLP offers a framework which is specifically designed to help us understand sustainable transitions. MLP is the model which explains the processes of innovation and transition more effectively in three different levels of perspective (Verbong and Geels 2010). This model helps to understand transition as an interaction between niche innovation, embedded rules, and the outer environment (Verbong and Geels 2010).

Since a few decades ago, the model has been widely used in innovation studies to understand the activities and interactions of related actors and organisations which influence the development of innovation processes (Geels and Schot 2007). Moreover, the MLP framework is considered one of the effective models to conceptualise the dynamic pattern in the overall technology transitions (Geels 2011). Verbong and Geels (2007) explain that MLP emerged from evolutionary economics and the sociology of technology. They described that MLP helps to explore the interaction between three different levels which are niches, regime, and landscape-level (Verbong and Geels 2007). Each of these levels means, niche innovations, socio-technical regimes, and more widened socio-technical landscapes (Verbong and Geels 2007). Geels (2010) present the MLP framework as an effective framework for understanding sustainable transitions. It also helps to make a clearer understanding of transitions. According to their research, transitions can be achieved as the results of these levels' activities and dynamic interactions (Geels and Schot 2007). The MLP framework is as illustrated by Geels (2006a) in Figure 2.

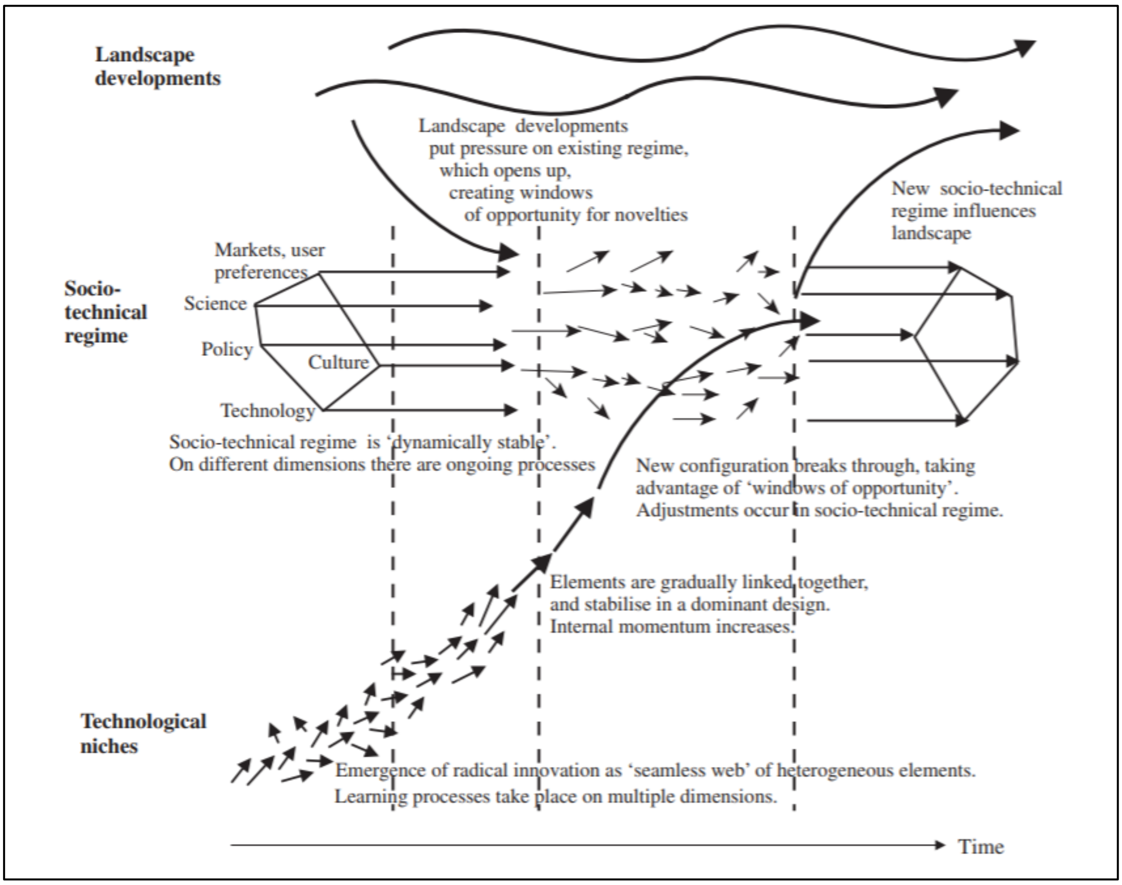

Figure 2 A dynamic multi-level perspective on system innovation (Geels 2006a)

The use of the MLP framework shows effectiveness in many aspects. In particular, it is used in many studies concerning technology transition studies, because the transition focuses on the process of change in a society fundamentally over a considerable period (Rotmans, Kemp et al. 2001); transition management research mainly deals with system change or system innovation, and also emphasises the adaptive behaviour of many actors (Rotmans, Kemp et al. 2001, Geels 2004, Kemp, Loorbach et al. 2007, Nill and Kemp 2009). In the aspect of considering transitions like the change from one socio-technological regime to another regime, this model is able to look at interactions between regime-level and niche and/or landscape level (Geels and Schot 2007). The systemic change is often called socio-technological transitions. It is because systemic change needs complex and dynamic interactions between actors in various fields. To sum up, transitions are a complex and time-consuming process by many actors (Geels 2011), and MLP is a useful model for explaining the dynamics of transitions by analysing the various actors' behaviour who belongs to these different levels (Geels 2014). Also, The use of the MLP framework is helpful to analysing of green innovation and transitions. MLP framework is used for understanding multi-dimensionality and structural change, as well as the technical studies of environmental innovation (Geels 2011). Moreover, this model focuses on technology-in-context and emphasis the co-evolution of technology and society. The most important point of this model is reducing the damages which can be occurred during the system innovation. In system innovation, there are not any simple causes and actors. Instead, there is a process of levels that simultaneously exist in various perspectives (Geels 2005a). Besides, the MLP aims to integrate the findings from different studies as an appreciative theory (Geels 2002). Therefore, this model allows us to analyse more wide problems in the innovation system, such as in the production system and consumption system (Smith, Voß et al. 2010).

Considerations for sustainable development are becoming getting widen and deeper than before. Also, it is required to escape from the fixed direction dependency (Smith, Voß et al. 2010). In this context, many researchers are satisfied with the MLP framework which has been used in research on innovation and has been able to improve the normal innovation pattern in wider socio-technological systems and open up more appropriate solutions, furthermore, MLP is an attractive model for many researchers because it provides a simple way of arranging and simplifying the analysis of complex and large-scale structural changes in production and consumption for sustainable development (Smith, Voß et al. 2010). For example, in a case study on water management and long-term climate adaptation, Gottschick (2018) introduces the impact that a coalition of actors could have on building capacity to respond to problems by using the MLP to access social technology structures and dynamics. Additionally, Rao (2020) uses the MLP to analyse the factors affecting the development of China's new energy vehicles and the resistance motive in marketing, and found that China's landscape and niche-level actors play an important role in innovation by promoting market growth and breaking through traditional issues.

2.5.2 Structure of the MLP Framework

The MLP framework consists of three levels, such as niche (micro), regime (meso), and landscape (macro) levels. Niches are the foundation of early innovation (Geels 2010). Socio-technological regimes are fixed and stable in many ways, and the socio-technological landscape is from the outside (Geels 2010). Each of these three levels forms a micro-level where fundamental ingenuity arises, a meso-level that accounts for the large scale of stability, and a macro-level which is an external environment that affects niches and regimes (Geels and Schot 2008).

To begin with the micro-level, niches are the basis of this level. Niches are the roots of innovation (Geels 2006a) and a regional level in the innovation process in which new skills and practices are appeared and are developed to enter the market (Geels 2005b). According to Verbong and Geels (2007), the basis of micro-level is a novelty and includes pioneers and inventors as the main actors to provide new products and services. In this level, technological niches form radical novelties which are unstable. Also, having been described by Kemp, Schot et al. (1998), they act as ‘incubation rooms’ protecting their novelties opposing established market selection. Geels (2010) described that the niches are the root of innovation. Therefore, pioneers, frontiers, and inventors are the main actors at this level. They introduce new ideas and ways to improve current products, services, and systems Geels (2010). Moreover, they try to make using small networks, niches develop their novelties as well as do their efforts to link with diverse actors and elements in a seamless web (Geels 2002). They try to provide advanced and/or new products and services (Geels 2002). By various learning processes and improving performances with powerful groups' support, niches can attain their goals for innovations (Geels and Schot 2007). Through their activities, innovations and transitions become possible.

Scholars divide niches into two basic types, market niches and technological niches focusing on the emerging environment of selection (Hoogma, Kemp et al. 2002). Market niches come from consumer's preference which is far from customs or specific contexts, and it is important because both producers and users of new technology recognise its potential capability (Hoogma, Kemp et al. 2002). On the other hand, according to Geels (2005b), technological niches are deliberately created by actors and supported by specific agencies including external actors, policymakers, entrepreneurs, and so on.

In a widened perspective, niches are similar to regimes, however, they are in the difference at two points. According to Geels and Schot (2007), both technological niches and socio-technical regimes have a similar type of structure and have characteristics of an interactive community. However, the size and stability are different, with regimes being bigger and more stable, whilst niches are smaller and unstable. Furthermore, although both niche and regime communities have particular rules to control their communities, at the regime level, these rules are stable and well-organised, while they are unstable at the niche level (Geels and Schot 2007). The important thing is, the development including stabilisation and breakthrough of niches can be affected and determined under the relationship with regimes, moreover, when niches have the potential capabilities somewhat to compete with regimes or to solve the bottleneck of the regimes, they can be more successful when entering the market (Markard and Truffer 2008).

Secondly, socio-technical regimes formed the Meso-level (Geels 2010). This socio-technical regime is Nelson's (2009) technological regime's widened version (Geels and Schot 2008). Bijker, Hughes et al. (1987) used the concept of a large technology system to describe a network that performs the functions of social infrastructure. Later, Geels (2002) added to this social aspect, changed the name of these systems to the socio-technical regime. After that, Geels and Schot (2008) explain that the socio-technical regimes refer to cognitive routines' sharing in community and development pattern within 'technological trajectories. Smith, Stirling et al. (2005) emphasise the importance of regimes level that, adding to select the pressure on the regimes at the landscape level and to choose available resources at the niches level, coordinating these things in the level of the regime is equally important in technology transfer.

The socio-technical regime is the core of technology transition which is coherent, stable with high interrelationships, aims to stress that not only engineers and scientists but also all kinds of businessmen, end-users, policymakers, social interest groups and associations share rules and practices (Geels 2002, Geels 2005b). The regime is stabilised under the influence of external and sometimes slow-changing social structures, including things such as cultural values, political ideologies, climate change, or demographic transitions (Fuenfschilling and Truffer 2014). Therefore, there are many interconnected actors and activities for achieving innovations at this level. According to Bijker (1997), sociologists argue that scientists, policymakers, users, and related interest groups contribute to form technological development patterns. This is also described by Verbong and Geels (2007) that, at the socio-technical regimes' level, new and innovative ideas of niches can be more developed by interactions of various relative actors including engineers, social groups, end-users, and politicians.

However, while regimes can provide stability to niches, by the movement for innovation in niches affected by landscape, regimes also can be affected and unstabilised (Geels and Schot 2007). Therefore, regimes factors are trying not only to keep the stability but also to manage various changes actively (Genus and Coles 2008). Where these dynamic activities take place, Verbong and Geels (2007) argue that a social technology system has three interconnected aspects that guide the activities of actors and social groups, regulatory, normative, cognitive rules, tangible and technical elements, whilst also dealing with related technologies and infrastructure, and contribute to the stability of existing and emerging new regimes. This shows that the actors are expanding their support for aligned activities to stabilise the existing systems in progress. On the other side of the socio-technical regime level, new configuration comes out. This comes from the alignment of the niche level's elements which are stabilised in their territories. This new configuration after overcome challenges of niche level, it takes advantages of 'windows of opportunity' for further developments or transitions (Geels 2002).

Thirdly, the macro level is also called the landscape level. By many scholars, it has been studies that government interference is involved in technology transfer (De Jong and Stout 2007, Ansari and Garud 2009). Given the political nature of the large social technology system, the technology transfer process at the level of the regime frequently includes carefully planned intervention by the government (Kemp, Rip et al. 2001, Rotmans, Kemp et al. 2001, Smith, Stirling et al. 2005). Therefore, both regimes and niches are brutal to free from the impact of the landscape. Landscape-level refers to the external environment of processes and factors affecting both, such as oil prices, economic growth, war, immigration, broad political solidarity, cultural and normative values, environmental issues, and so on (Geels 2002). Also, most are independent and autonomous (Kemp, Rip et al. 2001). It can be viewed as a set of factors that affect innovation and production processes without being affected by the outcome of the innovation process in the short and medium term. However, due to the changes in the environment, such as governmental decisions, usually, take place changes slowly (Schot and Geels 2008).

To put together, scholars' (Ulmanen, Verbong et al. 2009, Geels 2011) described that niches are the spaces of radical path-breaking innovations. For example, new practices and technologies through the protection space provided by R&D labs, pilot projects, small market gaps and policy facilitation markets are critical in the process of systemic change (Ulmanen, Verbong et al. 2009, Geels 2011). Regimes are dominant practices, technologies, infrastructures, rules, and beliefs that are shaped around existing systems (Geels 2004), and the landscape is an external factor affecting gaps and regimes, including spatial structure, political thought, social values, beliefs and macro-economic trends (Geels 2012).

As many studies have shown, the MLP framework is criticised for followings: it is less focused on socio-ecological or distribution systems such as inequality and poverty (Røpke 2016); when studying eco-friendly innovations, it has not fully addressed the consequences or effects of innovation and has shown a lack of cultural semantic research (Gillard, Gouldson et al. 2016); the fact that the upward transition was too biased (Smith, Stirling et al. 2005); and so on. However, MLP has served as a sufficiently effective framework, given that it has helped to provide a rich understanding of the transition process with various sociological ideas, by enabling the study on the interaction of the levels of its structure, as described above (Geels 2019).

2.5.3 The theoretical background of the MLP Framework

According to Geels (2005a), MLP uses the findings practically from a range of studies. He explains in his study (Geels 2006a) that Sociology of technology, Business Studies, Evolutionary Economics, the institutional theory can be a theoretical background of the MLP framework. Also, Verbong and Geels (2007) explain that MLP is derived from evolutionary economics and the Sociology of Technology, and that is the model for examining interactions in a more widen environment as well as between niche innovation and existing regimes.

According to Geels (2006a) explanation, the first theoretical background of MLP is Evolutionary Economics. Evolutionary Economics is an economic theory that Nelson and Winter (1973) systematically constructed the theory of research. Studies on evolutionary economics have focused primarily on business and economic development (Geels 2006a). Among the early evolutionary economists, Alchian (1950) summarises the developmental potential of evolutionary economics. He points out that in an uncertain situation, businesses should be able to look ahead and make the right choice through many of the currently available alternatives, arguing that accepting Darwin's law would create other possible assumptions instead of existing ones that have problems. He also proposes an understanding of the evolution of the market economy by understanding the evolutionary mechanism of living things, arguing that the mechanism of the mutation of biological evolution may appear to be an innovation in the market economy (Alchian 1950). After this, Winter proves that economic analysis is possible using the mechanism of evolution without the unrealistic assumptions of corporate rationality as suggested by Alchian (Winter 1971).

The technology attention was next, where technology was used as a means to explain economic activities (Geels 2006a). Nelson (1982) found that the mechanism by which companies adapt to real-world problems is to develop new products or improve existing products and business methods through R&D activities. Also, they developed a routine as a concept corresponding to a genetic factor because a routine plays a role in preserving and maintaining the various behaviours of the enterprise that enable them to stand out from the competition. If a company cannot preserve its competitive advantage through research and development, it is difficult to expect further adaptation or development, and it may deteriorate. (Geels 2006a) notes that their research has earnestly studied engineers and designers' work with research focused on technological change and that engineers and R&D managers are more likely to use cognitive heuristics (cognitive heuristics) to seek better results. However, if the routine is well established, it can be regarded as a necessary factor in the stable execution of both internal and external changes. Generally, companies have different organisational and cognitive routines, and they maintain and evolve various routines to perform their tasks reliably and to progress their successful products. However, unsuccessful things are not progressed and when different companies share their routines, they form technical regimes that can lead to technical trajectories at sectoral levels which provide direction for these technological developments to be stable (Geels 2006a).

Institutional theory can be said to have been initiated by Karl Marx and Max Weber (Scott 2001). In the 20th century, the institutional theory was accepted in many social and economic sciences, political sciences, and sociology. According to Geels (2006a), social groups of actors are coordinated and controlled by institutions where an institution can be thought of as a rule. The role of institutions (regulations) is to guide actors' actions and their insights or awareness. Also, according to Scott (2004), institutions are highly resilient social structures. From the perspective of the institutional theory, institutions with related activities and resources give social stability and meaning, and these institutional elements can provide continuity and certainty in the organisational, and also can keep the technology system intact (Scott 2001).

Scott (2003) divided the three rules of this system into the following: 1) Regulative / Formal: Significant by institutional economists, such as government regulations. There are economic processes and rewards, 2) Normative: often emphasised by traditional sociologists, such as values, role expectations, obligations, and accountability. It is related to the sociological process. 3) Cognitive: It has been emphasised by social intellectual psychologists. This can be seen in Table 1.

Table 1 Scott's three conceptions of institutions (Scott 2003)

Elements	Regulative	Normative	Cognitive
Basis of compliance	Experience	Social obligation	Taken-for-grantees shared an understanding
Mechanisms of influence	Coercive	Normative	Mimetic
Logic	Instrumentality	Appropriateness	Orthodoxy
Indicators	Rules, laws, sanctions	Certification, accreditation	Common beliefs shared logics of action
Basis of legitimacy	Legally sanctioned	Morally governed	Culturally supported, recognisable, comprehensible

Geels (2006a) explains that the institutional approach focuses on the behaviour of such people belonging to social organisations. People are influenced by the system, and by sharing and cooperating with norms, they can bring harmony and stability. Moreover, by sharing and linking various regulations and constraints, they can effectively cope with the social order and regime. Since regulations addressed in this way can create stability and strength at the regime level, the institutional background can be the theoretical support to explain the behaviour and norms of individuals and organisations at the system level (Geels 2006a). According to Zhang (2016), in some perspectives, the regime actors are institutional agents, which include governmental or quasi-governmental organisations. Geels (2004) put these rules and institutions into the socio-technical regimes and organised them as in Table 2.

Table 2 Examples of rules in different regimes (Geels 2004)

	Formal/regulative	Normative	Cognitive
Technological and product regimes (research, development production)	Technical standards, product specifications (e.g. emissions, weight), functional requirements (articulated by customers or marketing	Companies own sense of themselves (what company are we? what business are we in?), authority structures in technical communities or	Search heuristics, routines, exemplars) (Dosi, 1982; Nelson and Winter, 1982), guiding principles (Elzen et al., 1990), expectations (Van Lente, 1993; Van Lente and Rip, 1998), technological guideposts (Sahal, 1985),

	departments), accounting rules to establish profitability for R&D projects (Christensen, 1997), the expected capital return rate for investments, R&D subsidies.	firms, testing procedures.	technical problem agenda, presumptive anomalies (Constant, 1980), problem-solving strategies, technical recipes, 'user representations' (Akrich, 1995), interpretative flexibility and technological frame (Bijker, 1995), classifications (Bowker and Star, 2000).
Science regimes	Formal research programmes (in research groups, governments), professional boundaries, rules for government subsidies	Review procedures for publication, norms for citation, academic values and norms (Merton, 1973)	Paradigms (Kuhn, 1962), exemplars, criteria and methods of knowledge production.
Policy Regimes	Administrative regulations and procedures which structure the legislative process, formal regulations of technology (e.g. safety standards, emission norms), subsidy programs, procurement programs	Policy goals, interaction patterns between industry and government (e.g. corporatism), institutional commitment to existing systems (Walker, 2000), role perceptions of government.	Ideas about the effectiveness of instruments, guiding principles (e.g. liberalisation), problem-agendas.
Socio-cultural regimes (societal groups, media)	Rules which structure the spread of information production of cultural symbols (e.g. media laws).	Cultural values in society or sectors, ways in which users interact with firms (Lundvall, 1988).	Symbolic meanings of technologies, ideas about impacts, cultural categories.
Users, markets and distribution networks	Construction of markets through laws and rules (Callon,	Interlocking role relationships between users and	User practices, user preferences, user competencies, interpretation

	1998, 1999; Green, 1992; Spar, 2001); property rights, product quality laws, liability rules, market subsidies, tax credits to users, competition rules, safety requirements.	firms, mutual perceptions and expectations (White, 1981, 1988; DB Systemtechnikerg, 1994).	of functionalities of technologies, beliefs about the efficiency of (free)markets, perceptions of what 'the market wants (i.e. selection criteria, user preferences).

Sociology of Technology which is represented by social constructivism has focused on the social factors that affect the process of technology emergence rather than only focus on the effects of technology on society (Bijker, Hughes et al. 1987, Pinch and Bijker 1987). Effective collaboration within and outside of the organisation often relies on effective diffusion of information across areas related to innovation, and the transition to the sociology of technology can help explain both the interaction and impact of various actors when innovation is developed and implemented (Harty 2005). The typical research approaches in this area include the technological frame (Bijker 1987) and the actor-network theory (Callon 1999).

Geels (2006a) mentioned that technology is not merely a single entity, but it is actively created by human actions and social groups' actions. When technology is initially developed, there are a lot of problems and uncertainties about the precise technical characteristics, markets and user preferences. However, these things are refined orderly and steadily, then take the initiative in the market. Therefore, technologies, markets, and user preferences can be seen as a result of learning and interaction between various actors. In addition, although different actors come up with different ideas and solutions, they gradually gather a dominant idea and solution to reach an agreement. Also, the sociology of technology emphasises the importance of future expectations and strategic vision (Geels 2006a). Some researches (Van Lente 1993, Brown and Michael 2003) show that a common idea for the future provides direction to the whole activity, and it affects the activities of different actors. As the network expands and more elements are linked together by the connections of the various actors, the technology becomes more realistic, and the spread of this network becomes the process of forming a socio-technological connection (Geels 2006a).

2.5.4 The main areas for MLP's use and research

According to Genus and Coles (2008), researchers and practitioners are interested in exploring ways to improve their understanding of long-term technological changes, developing perspectives and methods for analysing technological changes, and studying how to apply them effectively to management and operations. Research on technological transition, such as system and management research, provides a better understanding of technological change, and in these studies, the MLP framework was used to analyse technological developments and help them settle firmly in society, as well as to explain the early stages of progressive technological development. In addition, the MLP framework has led researchers to be interested in the interaction of various actors, the social-technical structure and the behavioural-harmonious rules in it, particularly the role of external actors that had previously been ignored (Genus and Coles 2008).

According to Vellinga and Herb (1999), recently, system innovation has focused on the field of a sustainable environment because modern society is showing problems in many ways, for example, the agricultural sector is suffering as a result of its intensity in the production system, the energy sector is experiencing difficulties in handling CO_2 emissions due to its heavy dependence on oil, and the transportation system is showing a serious level of congestion. These problems, such as energy use, carbon dioxide emissions, and air pollution, are deeply related to social structures and activities, requiring changes in the system to be addressed (Vellinga and Herb 1999), and MLP, an analytical and exploratory way to understand system innovation, is considered a way to answer questions about how the transition to a new system is handled (Geels 2011).

The MLP framework has been used for analysing green innovations and transitions (Geels 2014). Geels (2006a) mentions that research flows in the sociology of technology in five fields, and the first research flow is the Social Construction of Technology (SCOT) which is the theory that claims that technology is a kind of social process by analysing the phenomenon of political, economic, organisational and cultural elements involved in the process of technological change; that is, technology is developed by social needs in societies and emphasises social groups that play an important role in the development of these technologies. Because different social groups identify the problems of the same technology differently depending on their interests, and the solutions to them differ (Bijker, Hughes et al. 1987), studies of the interaction and consensus processes of different social groups or actors are important, and the MLP framework may be useful here. The second research flow is the socio-technical approach of the Large-scale Technology Systems (LTS), which focuses on the system builders who integrate different types of elements into their work systems, who can be described as heterogeneous engineers who interact not only with technology but also with people, tasks, facilities (infrastructures), economies, and policies (Geels 2006a). The study of LTS construction and development that can solve these problems is important, given that the various factors involved must be placed in the right place for technology development and that much is needed to maintain in order to operate the initial unstable and vulnerable network.

The third research trend is related to the Actor-Network Theory (ANT) (Geels 2006a). This theory is a methodology that explores the social implications of science and technology in more detail and shows the view that technology has autonomy, establishes relationships with humans, and exerts its ability to act. Here, actors include human beings and artefacts, natural objects, social institutions, or techniques. Furthermore, networks are the actors' relationships that are created by actors, however, actors can demonstrate their ability when they are in that network (Latour 2013). According to Geels (2006a), the early stages of these networks involve narrow and small elements, but when innovation is made by technological advances, actors try to expand the network by adding other networks to make effective use of these elements. With these efforts, as networks (actors) are built and intertwined, technology becomes more and more real, and functions and forms become more robust and evolved. In other words, the use of MLP can be effective in studying technology phenomena and developments, noting the relationship between various factors and interactions.

The fourth stream of research studies is related to the expectations for future technologies or systems, the importance of strategic vision, and shared ideas for the future (Geels 2006a). This research field is used as research for successful technology or system development and as a strategic resource to attract other external actors (Brown and Michael 2003). The last stream is the study that examines what kind of effects and results can be given (provided) from the use of developed or advanced technologies or systems, which can also be linked to other innovative activities. For example, the MLP can be used effectively to study new user routines and new functions that actors (users) create, such as consumer adoption and usage activities, additional skills or products they want, and at what level they can be used more effectively as users become aware of and adapt to new technologies (Geels 2006a)

2.5.5 Critical points of view of the MLP Framework

As mentioned earlier, the MLP framework has been criticised in many aspects, although there are many areas of diverse and possible research. According to Genus and Coles (2008), there is a critical view that uses the MLP framework to explain technology transfer which requires higher clarity and reliability, thus making the case studies using the MLP framework be more difficult to be clearly structured. Also, because the meaning of the transition varies from case to case and is often unclear whether it is a niche innovation or a transition process, the MLP framework can point out that there are problems in defining, conceptualising and verifying the transition path. Furthermore, the fact that focusing solely on relationships with technology may ignore other social and critical cultural aspects is also a factor that MLP frameworks can point out (Genus and Coles 2008).

Geels (2011) summarised that the MLP model is criticised for the lack of agency, operationalisation and specification of regimes, bias towards bottom-up change models, heuristics, epistemology and explanatory style, methodology, and socio-technical landscape a residual category, and flat ontologies versus hierarchical levels. Among them, I would like to review the lack of focusing on the agency. According to Geels and Schot (2007), actors and their communities have different characteristics at each level and at the regime level, communities are stable and have well-coordinated and stable rules (Geels and Schot 2007). At the niche level, communities are relatively small and unstable because their rules are in the process and constantly changing and being made for the development of niches. Although each level has different characteristics, each actor acts strategically by calculating the best behaviour to achieve their goals. However, according to Geels (2011), MLP has been criticised for underestimating agencies in the transition process. As Smith, Stirling et al. (2005) mention, if the use of the MLP focuses too much on technology, it may impose limitations on making integrated analysis, including the role of an agency or actor. Also, more interest in the power of governance and the role of policies should be needed in dealing with socio-technical transitions and for doing this, the MLP also needs to embrace constructive approaches such as SCOT, ANT, and Constructive Technology Assessment (CTA).

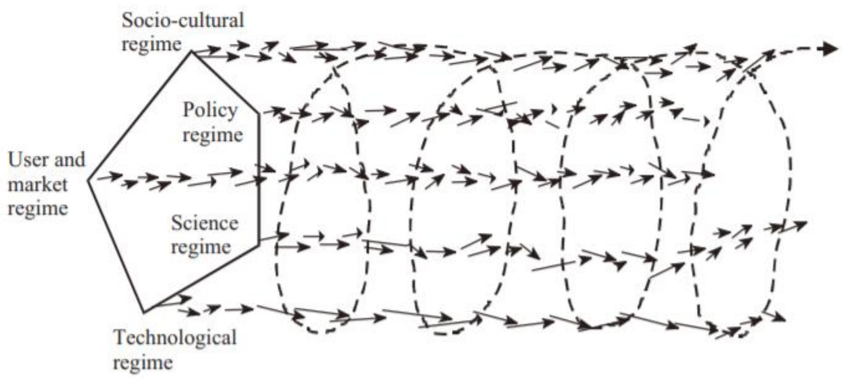

Figure 3 Alignment of ongoing processes in a socio-technological regime (Geels 2011)

Geels (2011) explains that various actors make networks and relationships by local practice, and in that relationships, rules are made and form a system. Innovation occurs as small parts of the activities are converged, coordinated and stably connected. Also innovation is the connection of a lot of different processes such as socio-culture, policy, markets, technology and consumer, therefore, the focus should be on the harmony and interaction of the whole process. In relation to this, many studies have been conducted to develop the MLP framework more including various agencies and actors, such as political power, society, culture, business (Rothaermel 2001), and networks of organisations (Tushman and O'Reilly III 1996) as in Figure 3.

To sum up, the stated effectiveness and usefulness of using the MLP includes:

- Able to support multi-disciplinary studies with a focus on systems and networks
- Able to look at and explain complex and dynamic interactions between actors in various fields
- Able to understand multi-dimensionality and structural change
- Able to integrate the findings from different studies as an appreciative theory for analysing broader problems in the innovation system
- By providing an integrative approach that accommodates multiple actors and dimensions, researchers are able to analyse broader problems in the innovation system

2.5.6 Technology Transition and the MLP Framework

The transition process is a complex and long-term process that can be obtained as a result of the interaction of various actors related to economics, science and technology, society, politics, markets, etc. (Geels 2011). Applying the Multi-Level Perspective (MLP) to this transition process helps to extend the analysis from technical products to social technology systems. The reason is that the different levels of systems, including technology, supply chain, market, regulations, social culture and practices, are interdependent and jointly evolving (Geels 2004). Interaction at each level can be shown as follows: first, innovation at the niche level is primarily through the learning process and many organisational activities supporting innovation, and activities at the regime level provide a variety of support and opportunities for these innovations. In particular, the social technology system is a kind of rule that is included in the creation and development of technology, which serves to coordinate and assist technological innovation and the overall social environment surrounding it (Rip and Kemp 1998). The role of this adjustment is also associated with the activities of the landscape level in a broader range. Through the interaction of these three levels of connected processes and activities, creative products, technologies and services can penetrate and spread into the market. (Geels and Schot 2007).

	Micro-level	Meso-level	Macro -level
Identifiable configurations that work (artefact in context)	Artifacts (tangible arrangements, immutable mobiles), 'machines'	Technical systems	Mumfordian megamachine
↕ Merge into	Scripts, technical fixes	(Technical) regimes	Sociotechnical landscape
↕ Seamless webs	Artifacts ad channels of social/historical forces	Sectoral structures and strategic games	Patterns in transformations of socieity

Figure 4 The multi-layered backdrop of novelty and irreversibility (Rip and Kemp 1998)

In the technology transfer activity, the social-technical system is centred and connected in several directions. Rip and Kemp (1998) used 3 × 3 tables to present a variety of ways to view these systems in all directions as can be seen in Figure 4. The horizontal axis represents an increase in area by expanding levels from niches to landscape, and the vertical axis represents a variety of perspectives on the characteristics of social and technological structures, from the relationships and alignment of each institution responsible for each technology, showing how changes over time are networked and positioned reliably in different levels of background. Emphasising the relevant areas of socio-technical complexity in such a variety of areas enables an explanation of large-scale technological transfer (Geels 2018).

The technological transition is mainly linked to changes in actors, networks of social groups, formal, normative and cognitive rules related to social and technological elements, and in general, the transition is not easy because the current system is robust and stable (Verbong and Geels 2010). Such as transformation, system innovation, dynamics of the governance effect, and environments have been of main interest areas in technology transition, and the use of MLP makes the transition understand easily by explaining the various aspects of the interaction between niches innovation, internal regulation and external environment (Verbong and Geels 2010). Based on this idea, Verbong and Geels (2010) divided the transition modes into four types and they are transformation, reconfiguration, technological substitution, and de-alignment and re-alignment under multidirectional interaction's types and timing.

Verbong and Geels (2010) explain that to start with transformation is characterised by the pressure from institutions of regime level and the external environment of landscape level. Although the external pressure can create opportunities for various changes, the innovation activities at the niche level are immature to apply these opportunities. Therefore, transformations are mainly driven and made by external actors who have the power to change existing situations and environments. Here, external criticism of society, public opinion is very important because they put pressure on actors. If there are critics, the outside actors will respond to it, even in a small way. Also, even if there are no definite reformation activities, gradual changes such as a change of direction or a decrease in pressure level occur. Secondly, through reconfiguration, the innovation in niche-level can be developed. It is because actors at the regime level try to gradually reconstruct and change the primary system by adding and adopting niche innovation to their system to solve the problems and pressures from both inside and outside. Here, through the interaction between niches and regimes which develop and provide new elements and technologies, reconstruction of the existing system. Thirdly, in the type of technological substitution, landscape-level actors put pressure on regime-level actors who provide niche-level actors with growing opportunities. If niches are more stable and have more power develop by the interaction with regimes, they can grow further to expand their market presence or replace existing regimes when the landscape creates problems for regimes and causes them to become unstable. So, in some perspectives, in reconfiguration, the competition situation can be created between niche actors and regime actors. Lastly, with the type of de-alignment and re-alignment, the important changes of landscape-level bring problems to regimes level, and at this time, if the actors of regime-level do not respond well, regimes can become unstable, also the more these instability continues, the more likely it is to collapse. At this time, the innovation which comes from niche-level is taken as an alternative and positioned as a new principle or a new system by re-alignment.

As mentioned earlier, a transition is a change of system and related to various systems, such as market, policy, culture, economy, industry, technology and user. Therefore, to understand a transition process, it is necessary to understand the processes that each of these has. Geels (2006b) describes the MLP framework from the perspective of co-evolutionary innovation by explaining that the transition is active when there are three levels of interaction and support, and that levels of innovation can be classified according to the degree of structural stability and flexibility. That is, at the niche level, actors with ideas and skills of innovation form systems by increasing interactions between them, and regime-level actors overhaul both existing and new systems through various social activities, networks and interactions. At the landscape level, the environment for common evolution, such as society, culture, economy, technology and politics, is slowly changing and evolving to provide a background for the other two levels to work dynamically. In addition to this, Geels (2010) summarises that since these MLP frameworks consider the transition process to be a three-step connection and interaction that not only remains independent but also affects each other, multi-sided theories can be explained using their respective actuators and mechanisms, as shown in Table 3.

Table 3 Foundational assumptions in different ontologies (Geels 2010)

Ontologies	Causal agents	Causal mechanisms
Rational choice	Self-interested actors, utilitarian individuals	Decentralised choice by instrumental rationality
Evolution	Agents in population	Variation, selection, retention
Structuralism	Taken for granted deep structures	Deep structures operate ‘behind the backs’ of actors, influencing their views and preferences
Interpretivism/ constructivism	Individual actors with varying ideas and interpretations	Social interaction, construction of shared meaning, sense-making, learning, debates
Functionalism	Social system	Actors fulfil system needs, enacting roles, tasks and norms
Conflict and Power struggle	Collective actors (groups, classes) with conflicting interests	Conflict and power struggle between different collective actors

Relationism	Networks and ongoing relations	Interaction, co-construction, translation, alignment

2.5.7 Actors and Agencies of the MLP Framework

MLP framework on transition is one of the most commonly introduced concepts for frameworks to distinguish between different critical areas of transition. Some scholars cite the MLP to distinguish actors involved in niche, regime and landscape and to identify roles in sustainable transitions (Fischer and Newig 2016).

Niche actors:

Actors at niche-level appear mainly in protected spaces such as technology research institutes, projects assisted by other agencies, or small markets with special characteristics (Geels 2012), and maybe individuals or small organisations who want to innovate the social system, disseminate new technologies (Bergman, Haxeltine et al. 2008). They aim to become mainstream by adopting or replacing new and innovative social technology ideas or theories with existing ones (Brunori, Rossi et al. 2012). Actors at this level show a lack of stability and have characteristics that are difficult to define, and are less likely to be seen at other levels (Jørgensen 2012). Also, actors at this level show more behaviours that enable relatively diverse and innovative experiments (Raven, Schot et al. 2012), and try to expand their ground by establishing more widen social networks and various dimensional learning and arranging both internal and external activities to overcome their instabilities. (Rip and Kemp 1998). According to Geels (2012), in highly stable situations, niche-level actors may find it relatively difficult to achieve their goals, but they can create an innovative starting point for institutional change. By doing so, niches actors engage in radical innovations in knowledge development and diffusion, various business activities, market formation and social change (Foxon, Hammond et al. 2010). Moreover, since many parts are related to social change, many scholars have argued that government policies and support are important to help the innovation and development of successful at niche-level (Geels and Schot 2008, Hielscher, Seyfang et al. 2011). Supporting this, studies show that niches actors affected by changes in government policy and support are more dependent on government decisions than on other levels of actors (Fischer and Newig 2016).

Regime actors:

Regime actors include all actors involved in systems in various sectors of society, including markets, industries, science and technology, culture and policy, whose role is to allow innovation movements or ideas generated by the niche level to settle in the system through interaction in various aspects or to help or adjust to confront the existing one (Geels 2011). Smith, Stirling et al. (2005) explain that although regimes can be more stabilised by these activities, there is a chance to increase tensions from different fields' rules and systems because the actors who maintain existing rules, theories and systems take no account of the need of reformation and change, there can come into conflicts with actors who want to introduce innovations or include them in the mainstream. Regime-level's actors need to not only manage internal networks for sharing and arranging resources, but also interact with other levels' actors broadly in order to respond to pressure at a heterogeneous level and to develop adaptability (Smith, Stirling et al. 2005).

Landscape Actors:

Landscape-level means external environment (Coenen, Benneworth et al. 2012), this level includes social values and beliefs, government policies or pledges, and changes in economic and financial conditions both national and international (Foxon, Reed et al. 2009). According to Raven *et al.* (2012), this level is challenging to define actors, and activities that directly affect the other two levels are hard to find. It gives an indirect effect on activities at the other two levels, without being directly affected by those levels. This level can be divided into the external and internal environment. The external environment is determined by completely unpredictable activities such as wars and earthquakes which shock other levels. The internal environment puts pressure on niche and regime levels (Morone and Lopolito 2015).

In addition to dividing the actors at three levels of the MLP as above, many scholars have also studied the role of the Agency more specifically (Fischer and Newig 2016). Bos, Brown et al. (2013) refers to individuals or collective actors as participants at each level of activity seeking or preventing change. Moreover, (Fischer and Newig 2016) describes them as an agency, including more types of actors from a sustainable transition research perspective. Grin, Rotmans et al. (2011) explains that there are many agencies in which a particular transition takes place, and they affect the transition method and duration associated with the activities of actors.

The activities of these various actors are described more broadly, including interdependencies. According to Fischer and Newig (2016), actors at each level rely heavily on the results that can be achieved by performing their own functions and roles, and most actors rely heavily on each other, while the dependency among other types of actors is weak. For example, niche actors who are influential due to the changes in government policies and support are highly dependent on the government, while market actors who are sensitive to consumer needs and demand are heavily dependent on consumers. Fischer and Newig (2016) organise the results of their research on the roles of actors and agencies by planning existing literary works related to sustainable transformation, as shown in Table 4.

Table 4 Functions, dependencies and agency of different actor typologies (Fischer and Newig 2016)

Type	Actor	Function	Dependencies on Other Actors and Resources	Potential Influence on Transitions
MLP	Niche actor	New, radical social and technological ideas emerge, Knowledge development and diffusion, articulation of visions, entrepreneurial activities, market formation, the guidance of search activities, mobilization of resources, creation of legitimacy, overcoming of resistance to change, Can create a starting point for systemic change.	Successful niche emergence depends on changes in government policy and support.	The niche level is a protective space that supports more agency, and niche actors have limited agency.
	Regime actor	Supporters of transition by forming powerful coalitions to push through a reform agenda that fits incumbent regimes interests. Opponents of transition by downplaying the need for transformation.	To build up adaptive capacity, regime actors must articulate problems or directions and get involved in networks to share and coordinate resources.	The regime level itself can be either a source of or structure of the agency, regime actors have limited agency.
	Landscape actor		Changes at the landscape level have, for example, an influence on civil societies' participation in community-based innovative initiatives.	No activities; level itself provides no room for agency.

State, market, civil society and citizens	Government	The traditional role of providing financial resources at the early non-competitive state of innovations. The new role of creating niches through institutional work enabling experimentation.	Depend on job availability, tax incomes, economic growth and new technologies, depend on the wider public for re-election.	Limited agency (often perceived as a leading actor in transitions).
	Market	Bring competitive products and services to the market, Supporters of transition when being entrants, seeking new business opportunities. Opponents of transition when business with established technologies, not eager about alternatives.	Consumer pressure	Limited room for a unilateral agency: reasons for new ideas not spread in overarching structures of markets, patterns of final consumer demand, institutional and regulatory systems and inadequate infrastructure for change.
	Civil Society	Ability to get engaged in both regime stability and the pressuring of the regime. Pressuring of the regime: diffusing innovative niche ideas and practices, using lobbying and protests to unsettle the regime, pushing and encouraging regime actors to seek new solutions from niches, representing general landscape-level trends.	Through markets and politics, they can help to shape the landscape of civil society can unsettle the regime or contribute to stability.	Limited, for example, by reaching a critical mass.

Actors on different levels of governance	Actors on the local governance level	Framing issues of sustainability and the creation of effective policies. Successful bottom-up approaches for behaviour changes. It might create local acceptability for certain national policies and fiscal measures. Developing infrastructure and providing locations for experimentation. Niche managers.	Local initiatives depend on linkages with policy arenas on a higher level to be able to scale up.	Limited (see also actors on the regional governance level).
	Actors on the regional governance level	It May help to promote transitions on a broader scale when national/global actors can draw on successful regional transitions (dependency). Helps to transform a technology experiment into reality.	Achieve the greatest impacts with the help of their human and institutional capacities.	Weak agency. No laws can be changed. Legal enforcement of action is hardly possible. Administrative capacity is limited. Many incumbents are out of reach.
	Actors on the national governance level/Government	Organise key resource flow efficiently by managing flexibly targeted supply and pricing strategies. Can establish markets for sustainable innovation together with entrepreneurs (also dependencies).	Managing transitions depends on national actors and their real and perceived power.	Leading or structuring actor.
	Actors on the global	Can guide reform processes enacted by the	National governments have	Limited agency

	governance level	government. Priority for governing seems to be wealth accumulation.	partly given up political and economic sovereignty to multinational corporations and financial institutions.	
Intermediaries		Providing and distributing necessary information. Mediating function. Provide services. Connecting niche-level activities with regime-level institutions. Diffuse new technologies and practice through the regional level.	Resource dependency	Active agents

2.6 Innovation and Technology transition

According to Schumpeter (2017), innovation includes not only products, but also processes, materials, organisations, markets, new and improved products and processes, new organisational forms, applying existing technologies to new areas, discovering new resources, and creating new markets. Moreover, by the most traditional classification, innovation can be divided into product innovation which means developing new products or improving existing performance, and process innovation which new or existing processes are better developed through cost reduction.

Markard and Truffer (2008) noted that the innovation process is important because it has many consequences for suppliers, producers, customers, policymakers and society, and that the process relies on a variety of co-development including the construction of new social technologies, new market structures, and new actors and new institutional arrangements. Many innovation researchers have used two methods to analyse radical changes and these are research on new technologies focused on analysing specific innovation potentials which could have far-reaching effects, and technology conversion with the potential to replace existing ones (Markard and Truffer 2008). Also, the innovation system consists of a network of actors and institutions which develop, spread and utilise the performance of innovation, and studying these innovation systems is also used as a basis for policy proposals by comparing the functions of various innovation systems created through the interaction of actors and institutional networks (Carlsson and Stankiewicz 1991, Malerba 2002, Edquist 2010).

2.6.1 Definitions of Technology transition

By definition, technology transition is to transfer specific and systematic knowledge and functions of the relevant science and technology to other organisations to realise a specific purpose. (CCPSA 2002). Souder, Nashar et al. (1990) defined technology transfer as a management process that one party communicates until another party adopts the technology, in other words, the technology to be adopted was defined as the process of moving from one side to another, such as moving from developer to user or from one department to another. Camp and Sexton (1992) denoted the transfer of technology as the movement of technology knowledge, the process of delivering research results to potential users, and the transition from an early recognition organisation to a user organisation in the development phase. According to Eveland (1986), technology is the information used to perform tasks, and technology transfer refers to the transfer of technology from an individual or organisation to another organisation through a communication channel. In addition, technology transfer means a broader use of information generated by innovation (Gibson, Rogers et al. 1994). Winebrake (1992) described technology transfer as the process of applying technology, knowledge, or information developed by an agency for a particular purpose to other purposes in different areas of the organisation. Roessner (2000) noted technology transfer as transferring know-how, knowledge and technology from one institution to another, explaining that, in general, private businesses, government agencies and universities act as technology providers while schools, small businesses and small towns are technology beneficiaries. Also, in the case of large enterprises where technology transfer takes place within an organisation, technology transfer is a shift of ideas and concepts from research-related departments to production-related departments (Roessner 2000).

2.6.2 Technology Transfer Types and Characteristics

According to Lim (2007), there are some main factors that affect the performance of technology transition, such as technical characteristics, technology provider and innovator characteristics, and policy-based environment. In terms of technical characteristics, in early-stage of the invention and basic research, the joint research method is appropriate, whereas in the case of applied research for practical use, licensing is more appropriate, especially for inventions with the intellectual property right, such as patent that guarantee ownership. The characteristics of technology providers with high performance in technology transition are that they have not only high quality of researcher and developer, but also a system of inducement for this R&D to participate in technology transfer, as well as technology-absorption and financial capacities. Also, a policy-based environment that surrounds technology transfer is a very important influence factor, and is created in consideration of various industrial, political, and economic environments, such as markets and economic systems of each country.

According to Charles and Howells (1992), technology transfer can be expressed as a proliferation of complex knowledge sounds surrounded by levels and types of technology. Stewart (1979) also explained that defining a very broad range of technologies to include all knowledge related to economic activities means covering a wide variety of technologies, while also addressing the transition mechanisms associated with them. Technology transfer includes embedded knowledge such as products, plants, equipment, know-how, information, patents, learning, and the flow of information and knowledge at various levels of individuals or organisations (Charles and Howells 1992). Because it has been explained and expressed by various forms and scales, it is very important to understand the meaning of technological warfare broadly (Charles and Howells 1992). The process of technology transfer usually involves transferring innovation information from an organisation that develops and studies the technology to other organisations that want to accept the technology for their needs, and once products or services which applied the technology sold in the market, the technology transfer is complete (Rogers, Takegami et al. 2001).

According to Tsang (1997), the transfer of technology involves considerable resource costs, as technology varies from company to company, and has inherent implied and cumulatively. The technology being transferred is very diverse in forms such as product, mechanical equipment, human capacity, production and distribution system and marketing system (CCPSA 2002), and depending on the type of technology transfer method, various related actors and organisations will go through the transfer method. Depending on the degree of innovation, technologies that are transferred may vary according to their nature, such as new technologies, technologies that represent radical developments, technologies that have limited transfer history, and may vary in the transfer methods depending on organisations' or regional characteristics which require the transfer of technologies of the same classification (Davidson and McFetridge 1985). The types of technology transfer can be divided into technology-generated types to create new technologies by the R&D activities of the parties, technology transfer types to transfer ownership of the technology, and technology loan types that allow the other party only the right to use the technology while holding ownership of it (Lim 2007).

Technology transfer takes place through various channels of communication. Rogers, Takegami et al. (2001) defined communication in five channels. According to his summary, the first communication path is a spin-off. Spin-off refers to a new company consisting of individuals with core skills who were part of the parent company (Rogers, Hall et al. 1999), meaning that spin-off means transferring innovation to a new company formed around innovation. As more and more multi-layered spin-offs occur, the concentration of high-tech companies eventually forms, resulting in the creation of Technopolis, a phenomenon that is represented by high-tech spin-offs formed in the late 1980s and 1990s in Austin, Texas. The second route is licensing which takes permission or right to act on a particular product, design, process, etc. With this, License fees are the consideration for obtaining technical licenses, and licensing royalties are a significant source of revenue for research institutes. Thirdly, publishing can also be a path to technology transfer which is the most frequently used one. However, among them, academic papers which are a common type of publishing, are the most commonly used technology transfer activity in university research centres, but they are not very effective technology transfer means from the corporate point of view, as the purpose is mainly biased toward the delivery and exchange of opinions or information with fellow researchers (Rogers, Hall et al. 1999). The fourth can be meetings which involve interaction between people to people who exchange technical information. Finally, there are systems to transfer technologies with government support in many countries, such as the Cooperative R&D Agreement (CRADA) in the USA (Rogers, Takegami et al. 2001).

As like this, various methods, such as cooperative research, licensing, spin-off, joint venture, and M&A are used to transfer technologies, and when it comes with the risk, cooperative research has the lowest risk and risk is increasing as going to licensing, joint venture, M&A, also, spin-off, which directly commercialises technology through the establishment of a company, has the highest risk, but the higher the risk of technology success, the higher the return (Lim 2007).

2.6.3 Research Areas of Technology Transition

Technology transition is one of the important activities for economic development in developing countries, as it is a means of technology development to improve productivity. However, most of the effective cross-border technology transfers take place between developed countries, and technology transfers from developed to developing countries have not achieved much. Mainly, technologies for the production of certain products and services are required on knowledge of production, furthermore a certain level of education or mindset, therefore, if there is a large gap in general knowledge between countries, technology transfer in production hard to have desirable effects (Doopedia 2019).

As technology transfer is such an important part of the industry, countries have been making various efforts to efficiently transfer technology and ultimately induce commercialisation under the recognition of successful commercialisation of innovative ideas and R&D achievements is a key driver for economic growth and social development. According to a study by Lee and Son (2016), technology transfer refers to the process by which technology is shared between organisations and regions through legal authority, such as intellectual property rights, or official transfer of information, knowledge, and technology. For example, in the United States, with CRADA, a system designed to facilitate technology transfer through joint research agreements among research institutes, universities, businesses and governments, supports the use of funds, manpower and intellectual property rights between them, and the government supports overhead cost. Also, it gives research institutes the right to distribute intellectual property rights to companies and universities who are participating in joint research and development, and provides a certain percentage of cash compensation to researchers who have contributed to promoting technology transfer activities (Lee and Son 2016).

The multi-level framework is also widely used in research on technology transfer processes and systems. (Geels and Kemp 2012). Miller (1978) explained that the system is a collection of components that interact with the interrelationships between components, and the state of each element is limited, conditioned, and dependent on it. Geels (2010)' explanation, which technology transfer is an interaction between the niche, regime, and landscape, and the multi-level framework helps study these three levels of systems both independently and collectively, can be associated with the description of the above systems.

Many studies of these systems related to innovation and metastasis have been carried out in different disciplines. The concept of a national-level innovation system was developed (Freeman 1988, Lundvall 1992, Freeman 2002). The national-level innovation system has since been studied divided into regional innovation systems (Muller and Zenker 2001, Mattes, Huber et al. 2015), sectoral innovation systems (Malerba and Orsenigo 1996, Cooke 1998, Malerba 2002), and technological innovation systems (Kemp 1994, Carlsson, Jacobsson et al. 2002, Geels 2002). This shows that it is being studied and proposed from a complementary perspective (Carlsson, Jacobsson et al. 2002, Chang and Chen 2004). From a widened perspective, the concept of LTS is also one of the approaches of innovation systems (Giikalp 1992, Markard and Truffer 2006). Markard and Truffer (2006) focused on the radical innovation process, particularly from the technical perspective.

Based on the studies which explain technology transfer as the interconnection of various factors, at first, national-level innovation system emphasises the interactions of various actors and complexity in all levels including not only industry, company, policy, technology-related actors and institutions, but also universities, research institutions, and governments (Freeman 1988, Lundvall 1992, Freeman 2002). The interactions between these organisations and system components, such as institutions, vary widely (Edquist 2010). They can compete with each other, but they can work together, they can trade things like goods, services, or knowledge. Agencies can also support each other and face conflict (Edquist 2010). The studies of sectoral innovation systems are based on the concept that innovation is not interdependent between industrial organisations, but rather on the influence of technological regime which characterised by different sectors or combinations of characteristics, such as organisational characteristics, capabilities, and knowledge base, of different industries, and the use of MLP enables dynamic analysis (Malerba and Orsenigo 1996, Cooke 1998, Malerba 2002). Besides, a lot of research on technological innovation systems which explain that there are many technology systems in each country, and the actors, institutions and relationships associated with them evolve and change over time, are interested in technologies that can be shared and reduce barriers between industries (Kemp 1994, Carlsson, Jacobsson et al. 2002, Geels 2002).

There are also many studies of actors in technology transfer. For instance, Musiolik, Markard et al. (2012) studied how actors collaborate through networks and combine resources from networks to form a broader innovation system. Quitzau, Hoffmann et al. (2012) have found that policymakers play a very active and creative role in the transition process. Bakker, van Lente et al. (2012) focused on the role of automakers and policymakers and studied the expectations and roles which they played in the process of technology selection, showing the importance of policy support for innovative technologies. Konrad, Markard et al. (2012) selected companies and laboratories as the central actors, and studied the expectation of groups in the organisation in relation to the innovative systems and argued that laboratories could be the centre in the field of innovative technology when expectations change or collapse.

Table 5 The Concept and Characteristics of Technology Transfer System (Hyun and Oh 1997)

Classification		First-generation technology transfer	Second-generation technology transfer	Third-generation technology transfer
Underlying concept		Superior technology replaces inferior technology	Technology flows once the link between developers and demanders is established	Systematic management is required to succeed in technology transfer
Technical characteristics	Completeness	High	Medium	Low
	Possibility of success	High	Medium	Low
	Originality	Low	Medium	High
Tech. flow		One-way	Partial bi-directional	Multiple directions
Technology Transfer Lead		Research-lead	Research-led, demand-driven	Collaborative lead by researchers and demanders

Participation by the technology implementer		Minimal	Passive	Active
Major Technology Transfer Mechanism		Passive technology transfer mechanisms, such as academic society, journal, etc	Consignment Development, Sponsorship, Centrist Technology Transfer Mechanism	New Technology Practicalisation, Increase of Joint Research Projects, and Active Technology Transfer Mechanism
Technical Supplier Characteristics	Attitude	Passive	Reactive	Proactive
	Programme	Legal	Administrative	Marketing
	Organisation	No organisation in charge (research centre)	Affiliate or support organisation of R&D functions	Organisations with independent functions/activities
Technical flow	Flow volume	Very limited	Moderate	Significant
	Range	Task unit	Agency unit	Network unit
Government role	Technology transfer policy	None	Technical Propagation (Diffusion)	Maximising R&D Investment Effectiveness through the Development of New Technology Practicalisation Technology
	Institutional readjustment	None	Research and Exchange Promotion Act of the Cooperative Research and Development Promotion Act	Reinforcement of technology protection and creation of network-building technology brokerage agency
	Investment	Investment to expand science and technology assets	Investment cooperation research and operation of pro-ham, etc. for the establishment of the	Regional technology transfer network deployment and technology transfer programs, techno mart, etc.

			industry-academic association system	

Various technology transfer models have been studied according to the types and subjects of technology, the scale of technology adoption, the actors and activities needed to increase the chances of success in technology transfer. Hyun and Oh (1997) summarise the various characteristics of technical warfare according to the system concept as shown in Table 5. Also, technology transfer is characterised by the interaction of different layers and actors, system integration and complex networks, and Bessant and Rush (1995) studies have identified the various components needed to learn, absorb and assimilate new skills needed for successful technology transfer to the organisation.

2.6.4 Technology Transition Models

Davis (1986) explains how new technology is being used through the Technology Acceptance Model (TAM) as shown in Figure 5. He explains that users decide whether to use or reject technology by considering two aspects of the new technology that was designed. That is, when you introduce people to new technology, they choose because the technology is not useful or will be useful and the reasons for these two choices are divided according to the field of technology and the tastes of the people who will use it (Davis 1989).

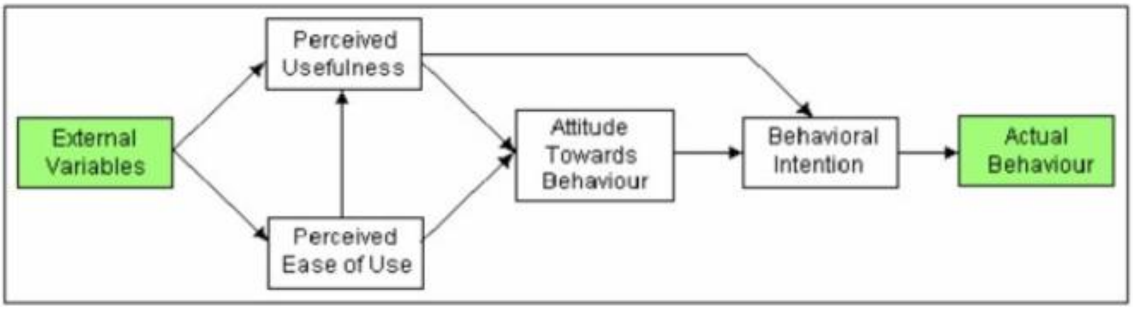

Figure 5 Technology Acceptance Model (Davis 1989)

Thus, the core concept of TAM is that the individual's attitude toward the use of technology is jointly determined by perceived usefulness and perceived ease of use. (Robinson Jr, Marshall et al. 2005). To explain this, Davis (1986) argued that the two factors, given use and use, had the most important effect on people's decision to use technology. Perceived usefulness refers to a tendency to use or not use technology to the extent that people believe it will help them do their jobs better, while perceived ease of use means considering how difficult it is for a person to use the technology, and how much greater the benefit of the use is than the effort to use it (Robinson Jr, Marshall et al. 2005).

Davis and Bagozzi et al. (1989) described the level of technology acceptance by integrating this perceived usefulness and perceived ease of use with the TAM. Davis and Bagozzi et al. (1989) explains that perceived usefulness is a more important concept to predict whether people will accept or not when some new technology emerges compared to ease of use. Once users are somewhat familiar with technology and systems, they choose to use technology with more meaning than ease of use, how beneficial it will be (Davis, Bagozzi et al. 1989). However, in their study, Robinson Jr, Marshall et al. (2005) argued that the received instance of use is more directly related to the user's choice of technology, and explained that the external factors that affect this include the length of time the technology is used, innovation, services that support the technology, and the level of experience and ability required to use the technology, as in Figure 6. According to them, many of these external factors play an important role in making decisions about the acceptance and use of real technology by the user through the received instance of use and the received use (Robinson Jr, Marshall et al. 2005).

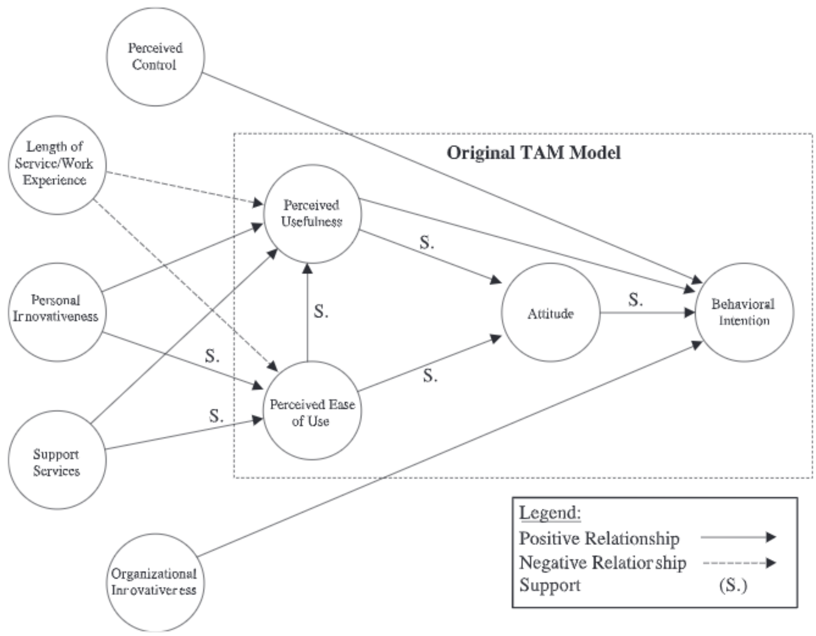

Figure 6 Structural model and hypotheses supported (Robinson Jr, Marshall et al. 2005)

Moreover, according to Greenberg (1996), the reasons for resisting new technologies include the anxiety of using new technologies, which can cause losing jobs or reducing income, the fear of not knowing enough about new technologies, the threat can come from using new technologies which may change social relationships with colleagues or organisations, the failure to recognise the challenges which you need to take new technologies, and the probability to encounter existing life or work habits which may be caused by using new technologies.

Resistance to these new technologies can come in many forms because they are as complex as the organisation or society to which the user belongs, and Rose and Bearman (2013) summarise these methods of technical resistance in five ways. First, users show resistance to adopting new technologies against the consequences of service quality, which is because they are uncomfortable in learning new technologies and their appearance (Stam, Stanton et al. 2006). The second is that it shows various questions and points out shortcomings due to lack of reliability, which Prasad and Prasad (2000) explain that users constantly ask questions about the negative possibilities that new technologies present that result from lack of confidence in new technologies and refuse to use them. Thus, as this case intensifies, it may require a technical design that must be redesigned (Smith and Douglas 1998). The third form of technical resistance is not to use the technology correctly (Rose and Bearman 2013). Jian (2007) found in his study that users who feared the use of new technology would harm their social relationships if they resisted the use of it or did not use it as intended. Prasad and Prasad (2000) summarised the resistance of new technology in the workplace as can be seen in Table 6.

Table 6 Summary of Routine Workplace Resistance (Prasad and Prasad 2000)

Discursive Constitutions	Key Participants	Construction of Motive	Types of Action
Owing Resistance	Nonmanagerial employments (nurses, record clerks and assistants, receptionists)	Direct Acknowledgements of International Opposition	• Interruptions and Questions During Training Sessions • Working with Manual Methods • Proxy Grievances
Naming Resistance	Managers, Supervisors and Nonmanagerial Employees	Attributions of International Opposition	• Careful Carelessness • Flooding the Basement
Indirect Resistance	Managers and Supervisors	Attributions of Nonintentional Opposition	Employee Reinterpretation of Managerial Discourses

The fourth is to meet compliance requirements. Predicting compliance is that, at first, it acts and follows as if it were using new technology (Mahoney 2011), but eventually takes actions that are abandoned or rejected for various reasons. The fifth form of technical resistance is apathy, in which case, users at first appear indifferent and uninteresting, simply thinking that the new technology is not helpful to their work, but eventually reluctant to use the new technology. Finally, the form of sabotage can be seen as the strongest technical rejection. If actions continue to point out the appearance and shortcomings of the various questions mentioned by Prasad and Prasad (2000) in the weakest form of rejection, they may lead to the form of sabotage.

Resistance to new technologies does not necessarily have a bad effect. Mabin, Forgeson et al. (2001) described it as rather a good thing because technology resistance is an opportunity to discover the problems or weaknesses of new technologies that have not been discovered before. Also, Lapointe and Rivard (2005) showed that resistance to new technology plays an important role in eliminating problematic technologies. Technical resistance is not simply a rejection of the use of technology and there are good reasons for most resistance. It is important to understand the root cause of resistance while respecting the problems users feel, given that technical resistance often provides an opportunity to avoid undesirable consequences that can be caused by blindness and compliance with new technologies (Rose and Bearman 2013).

If so, it is necessary to think about how to minimise user resistance to these new technologies, and Rose and Bearman (2013) compiled the following methods for minimising resistance: 1) Involve users in the process: by engaging people in the process of change, new technologies can be understood for what purposes and how they are designed to be applied, and the inconvenience that may arise when first encountered without knowing the technology at all can be reduced as much as. In doing so, users get a sense of ownership and actively participate in changes (Leonard-Barton and Kraus 1985, Nilakant and Ramnarayan 2006). 2) Choose participants that are appropriate for the change process: Since not everyone in the organisation can participate in the change process, it is important to select the most appropriate participants (Leonard-Barton and Kraus 1985). Organisations should choose participants who are trusted and actively involved, and Nilakant and Ramnarayan (2006) explain that connectors with a wide network, experts with social knowledge and skills, and Salesman, who is advantageous in persuading others, are appropriate participants. This is because people can understand technology quickly, make decisions correctly, and spread technical knowledge effectively to people in other organisations (Nilakant and Ramnarayan 2006). 3) Application of the best use of marketing: Leonard-Barton and Kraus (1985) argue that the implementation of new technologies should be seen as marketing efforts, including research on user needs and preferences. If people think that participating in a marketing survey contributes to the advancement of technology, they will have a sense of interest in that technology, which will support it and spread it more actively to others, and this leads to reduced technical resistance (Rose and Bearman 2013), 4) Target the right people in the right way: it is necessary to find out for some reason why they resist technology. Also, identifying those who are expected to resist before implementing the new technology minimizes technical resistance and helps the new technology become available to the organisation (Davis and Songer 2008), 5) Persuasion: According to Cialdini (1984), people are more sensitive to what they can lose than to guarantee what they get. Therefore, if you want to persuade people to accept change, you must explain the positive aspects of the change and the negative aspects of it that you might encounter if you do not change, 6) Training: A well-designed training should be done for the purpose because uncertain or insufficient training can have adverse effects, 7) Leading to voluntary use: Hartwick and Barki (1994) found through a guidance system study that voluntary technology and user participation in the design process were closely related, which led to many negative comments from users when the system was required to be used. When technology is used voluntarily, the benefits of using technology within an organisation increase and the negative atmosphere decreases (Kirkley and Stein 2004). In many of these ways, technical resistance can be effectively controlled, and new technologies will bring expected benefits by fulfilling their intended objectives (Rose and Bearman 2013).

Concerning organisations, Mayer and Blaas (2002) explain that technology transfer is becoming an important strategic tool that plays a major role in expanding business for small and medium-sized enterprises. Because of the relatively small scale of business and the limitations of various resources needed to develop new technologies, it is also very important for small and medium-sized enterprises which are hard to develop new technologies themselves to acquire technological resources through cooperation or transfer from other agencies (Morrissey and Almonacid 2005). Micro, Small and Medium Enterprises (SMEs) play a central and important role in the global economy as a major source of technology, innovation and employment (Robinson 2008). SMEs may indeed have less access to new technologies or innovations than large companies because they have simple structures and high flexibility and are very sensitive to costs. Therefore, acquiring new skills and skills can be an important challenge to survive in a rapidly changing global industrial environment and improve competitiveness (Hashim 2007). Ramanathan (2000) argued that in today's business environment, a variety of technology transfer models are being used depending on the nature or purpose of the technology as well as the individual or organisation's motivation for exchanging the technology. SMEs must have the ability to cope with new technology trends because new technologies must identify and overcome their impact to succeed and survive in the global market (Ashekele and Matengu 2008).

In the 1970s, technology transfer linear models were developed (Bessant and Francis 2005), and technology transfer in the 1980s, in the broader context of economic development, emphasised the study of delivery models for specific technologies (Hope 1983). According to Schlie, Radnor et al. (1987), there are a lot of factors that can affect the whole process of the technology transfer from planning to implementation, and they include the individuals or organisations that exchange technology and their attitudes to accept it and operational policies such as the ability or reliability to accept it, the system or model for effectively transferring technology itself, and the wider range of regional factors, political factors, and other factors surrounding them. In the 1990s, a study of models highlighting the importance of learning at the organisational level as a key factor in promoting technology transfer (Figueiredo 2001). The technology transfer model of Schlie, Radnor et al. was effectively used in

Chungu and Mandara (1994)'s study to show how the parties to the technology transfer to different layers of the environment are affected. This model using interactions of these various factors can also be described in conjunction with the multi-layered interactions shown in the MLP framework.

Gibson and Smilor (1991) saw technology transfer as a result of a process that began with scientific research and expanded to development, financing, manufacturing and marketing, and introduced a model with three stages: technology development, technology acceptance and technical application. In this model, technology development is the transmission of technology from one place to another through various methods, and the quality of the technology being delivered is very important. Because if a developer develops and announces a good technology, potential users will naturally find it, so good technology can spread naturally by themselves without too much effort (Devine, James et al. 1987, Hyun and Oh 1997). Technology acceptance refers to the stage in which new users understand and accept technology through the act of providing it to new users. In addition, the stage of technical application means the stage in which new users use technology to create value and make practical use of it. The model was then further expanded by Sung and Gibson (2000), into four stages like knowledge and technology generation, sharing, execution, level, and commercialisation.

Meanwhile, Abdul Wahab, Rose et al. (2009), divided current technology transfer models into knowledge-based perspective and leading organisational perspective, and because the technology transfer process requires not only the transfer of knowledge, but also absorption and use (Prusak and Davenport 1998), research from these two perspectives could explain what characteristics and behaviours the actors' involved show in knowledge transfer, absorption and use. According to Tenkasi, Mohrman et al. (1995) knowledge can be applied in many ways, but the failure of the knowledge delivered is due to the inability of users to understand it, so technology developers are responsible for delivering it correctly in appropriate ways so that users can understand and adopt it. Knowledge consisting of information and know-how is regularly expressed not only by individuals but also by members in the social community, in which the entity is engaged in technological warfare in the operation of knowledge within the organisation (Kogut and Zander 1992). In particular, Rebentisch and Ferretti (1995) described technology transfers as transfers of knowledge assets between organisations, focusing on how much effort should be made to transfer various types of technology through their technology transfer models, how the organisation's capabilities can affect the technology transfer process, and emphasising the importance of interdependence between the characteristics of technology and the organisations receiving it.

Nonaka (1994) complemented the Kogut and Zander (1992) model to explain the transfer model of knowledge, especially focusing on the process of which knowledge is generated at the organisational level through the continuous exchange of implicit knowledge and explicit knowledge. According to him, the transformation and movement of knowledge go through four stages: the socialisation process in which an individual delivers knowledge to another person, the externalisation process in which an individual who brings knowledge adds tacit knowledge to create new knowledge that can be shared by the entire organisation, the third in which knowledge is combined with knowledge gained from various places, and the internalisation process in which new knowledge is utilized and embedded in the organisation (Nonaka 1994, Nonaka and Takeuchi 1995). The organisation's knowledge creation process can bring the greatest effect when these four processes interact, and develop over the organisational network so that organisational innovation and learning can eventually be achieved (Nonaka 1994, Nonaka and Takeuchi 1995). Similarly, Nevis, DiBella et al. (2009) introduced a three-step model of knowledge acquisition, knowledge sharing and knowledge utilisation. According to their explanation, knowledge acquisition means the activity of having or creating knowledge through the development or creation of skills, insights, relationships, and knowledge sharing is the activity or process of disseminating the knowledge learned to other individuals or organisations. Also, the use of knowledge means that knowledge is widely available through various learning activities.

According to Spender and Grant (1996), the issue of how to manage a company based on its management strategy, namely its relationships with competitors, customers and suppliers, has long been considered a key task for management, and although information and knowledge are essential factors in establishing such a strategy, managers have focused more on what they need to know, rather than on their organisation's knowledge management. However, many papers have demonstrated that responding to changes in the environment is ultimately related to how well the knowledge of the organisation can be understood, and the interest in organisational knowledge initiated by academic research is also linked to the entity steadily, and managers are gradually beginning to pay attention to the operation of the entity's workforce (organisational members) and the management of technical knowledge which they possess (Grant 1996). In addition, the growing interest in organisational competency has increased the interest in implicit knowledge embodied in the organisation (Spender and Grant 1996). Grant (1996a) observed that knowledge is an important productive resource in terms of contribution to added value and strategic importance, and how well knowledge can be delivered depends on the ability of the person or organisation to receive knowledge.

Knowledge of science and technology, which is specialized in many ways, has attracted the attention of scholars, and research has been conducted from various perspectives throughout society to broaden their understanding of science and technology knowledge (Pavitt 2005). Many studies on organisational learning demonstrate the importance of social interaction, learning and sharing process systems for learning and knowledge creation (Nonaka 1994, Argyris and Schön 1997). This is based on Polanyi's (1966) argument that most of the knowledge is subjective, implicit, and cannot be easily documented and communicated. Lam (2004) considered an innovation process as the knowledge creation process which develops new knowledge to solve new problems, and emphasised the importance of organisational knowledge, explaining that it is the accumulated knowledge of the organisation stored in rules, procedures, daily routines and sharing norms that guide problem-solving activities and interaction patterns among the members. In addition, Brown and Duguid (1991) and Lave and Wenger (1991) explain that members of the organisation shared identity and perspective by repeating practice through work experience, which is related to Lam (2004)'s explanation that group work provides an essential place for knowledge development and transfer because practice develops the sharing and awareness of perspectives to promote knowledge transfer. Argyris and Schön (1997) describes the organisation as a cognitive space for learning and developing knowledge, and the concept of core competency (Prahalad and Hamel 1997) describes the accumulation and reliance of pathways in accordance with the organisation's learning and knowledge creation activities.

2.7 Rail Technology (in Europe)

As the size of railway markets has expanded globally, fierce competition has been taking place among railway technology-holding countries to ensure a smooth entry into the overseas railway market and secure markets. In terms of technology, the use and expansion of international standards are required and, if not, entry into the market itself may become impossible. Therefore, many countries have continued their efforts to take various measures to meet the requirements of international standards to compete in the global market (Schut and Wisniewski 2015). According to the Technical Barriers to Trade (TBT) Agreement of the World Trade Organisation (WTO), which aims to ensure that member states do not create unnecessary obstacles to trade based on international standards, in the event of a problem about technical specifications and specifications in the trade situation, international standards must be followed (WTO 2020). Therefore, in the case of Europe, the development of technologies aimed at the continued development of the railway industry, the readjustment of laws and standardization within the European region, and the implementation of numerous European Norms (ENs) in the railway sector as international standards. To this end, the Technical Standards for Interoperability (TSI) for the integrated operation of the EU region and numerous standards of each country are integrated into the form of the international standards (Baek 2015). These European railway technical standards are managed by the European Railway Agency (ERA) and the European Committee for Standardization (CEN), and European railway technology standards serve as a guide for technological homogeneity and interoperability within the EU region (CEN 2020).

EN is designed to facilitate trade between EU member states and promote industry-level unification (CENELEC 2019), and it is responsible for planning, editing and selecting European Standards. EN is ratified by one of three European Standardization Organisations (ESO), CEN, CENELEC, or ETSI, aims to facilitate trade and industrial-level unification among EU member states because each member country is to abolish existing national standards and to enforce mandatory adoption of them, the EN standard is implemented as a national standard for each EU country (Kim 2013). Because EN promotes international trade by ensuring the compatibility and interoperability of parts, products and services, and benefits businesses and consumers in terms of cost reduction, performance improvement, and safety enhancement, it is developed and organized through a process of knowledge sharing and consensus among stakeholders, including business, consumer and environmental groups. The deliberation of technical standards in the enactment of EN standards is established and operated by the Technical Committee of the European Standardisation Organisation (Baek 2015).

According to Kirchner (2007), there may be some problems with the approval process of multiple member states in terms of whether railway technology is appropriate for EN, such as mutual trust, because it may be unclear whether a separate review of other member countries' approval is made, the level of information or the details of documents to be submitted for international use may differ, and the roles and responsibilities of the various agencies involved are different. In addition, problems can arise because the level of transparency in procedures and the level of complexity in the certification process vary widely.

Interoperability refers to the level at which two or more items or programs can be used together, or the quality at which they can be used together (Combley 2011). The definition of interoperability in railway terminology is given in 2008/57/EC (ERA 2012) that is described as the ability of a railway system to achieve the level required for railway operation, promoting safety, uninterrupted movement of trains, which depends on all regulatory, technical and operational conditions that must meet the essential requirements. In other words, interoperability refers to the effective operation of two or more transport systems and the effective implementation of customer requirements for the transport system together (Mulley and Nelson 1999). Europe has developed railway technology based on different systems in the past, but Europe has standardized the European region in developing technology and legal systems in order to promote convergence and sustained development of the railway sector in line with EU integration and the continued progress of European development (Baek 2015).

European railways, each based on national systems, were difficult to internationalize due to wide differences in technology and operations, high costs have been a problem, and were less competitive than other means of transportation (Holvad 2015). In railways, the implementation of interoperability, though with the same goal, shows the unique exceptional complexity and difficulty of different countries due to different administrative, legal and technical conditions (Jacyna and Szkopiński 2015). As a way to address this, strengthening interoperability of railway systems, which are part of the

European Railway Reform Initiative, has been prioritized since the mid-1990s to contribute to reinforce competitiveness and to establish the TSI for its mandatory implementation (ERA 2012). The aim of the TSI is to make it easier for train operators to use systems from other member states by ensuring that all infrastructure, equipment and rolling stock are compatible, and to assist the EC railway manufacturing industry by adopting common standards (Butcher 2014). Increased interoperability of technology and systems will gradually increase common areas in railway systems and infrastructure among countries, thus strengthening the scope of market entry and providing opportunities to reduce costs associated with technology use and transfer. In addition, integrated railway technology and systems can contribute to the large-scale economic creation of the railway industry, leading to the interests of railway operators and users (Holvad 2015).

Since the adjustment to the interoperability of these railway lines is to adjust all the railway devices, structures and functions, and the technical and operational variables associated with the operation of trains, all variables must be adjusted to meet the essential requirements of TSI in consideration of the interests of many stakeholders in the railway transport system, including infrastructure managers, railway workers, customers and railway facility product producers (Jacyna and Szkopiński 2015). Following the Directive (EU) 2016/797, TSIs are technical and operational standards that must be met by each subsystem to ensure the interoperability of railway systems in the European Union and meet essential requirements, defining structural or functional subsystems that form part of the European Union's railway system, specifying essential requirements for each subsystem, considering safety, reliability and availability, health, environmental protection, technology compatibility and accessibility, and determining technical specifications to meet them (EU 2016).

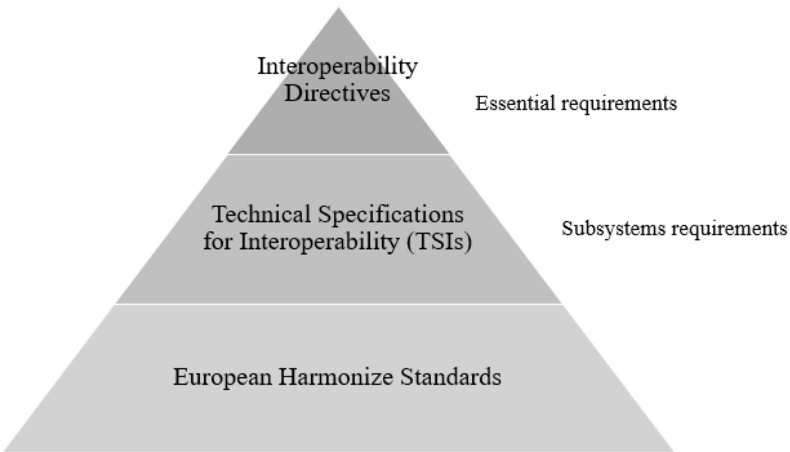

Figure 7 Legislation pyramid for the railway sector adopted from ERA (2010) (Holvad 2015)

Rail technologies in Europe are managed by the European Railway Administration (ERA) and the European Committee for Standardisation (CEN). The overall structure of the European framework for the technical harmonization of railways consists of interoperability guidelines, TSIs detailing the requirements and conditions that each component must meet, and European Standards developed by the European Organisation for Standardization at the request of the European Commission, as shown in Figure 7. As explained by Holvad (2015), interoperability guidance is introduced or amended following the joint decision-making process between the Council and the European Parliament, and the Member States must change this order to national law and must follow it essentially. The TSIs are mandatory across member states and must be implemented without changes in each country. To this end, the national rules are lower in the TSIs, except for ensuring technical compatibility with existing systems not designed to meet the TSIs, where special provisions are required, or where the country specifically provides solutions. European harmonized standards in the bottom level in this figure include European Standards developed by the European Organisation for Standardization at the request of the European Commission. Figure 8 shows how each regulation is made and modified in terms of the role and participation of key stakeholders (Holvad 2015).

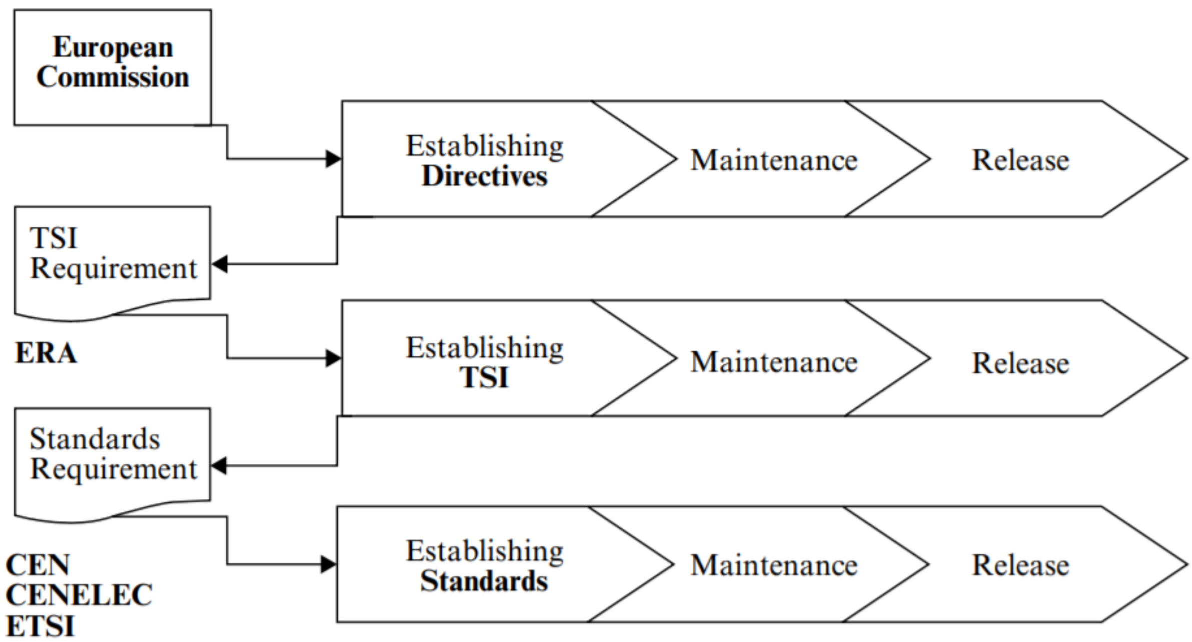

Figure 8 From Directives to standards in the European railway sector (Holvad 2015)

According to Beak (2015), if the technology developed in the country is recognised in the global market and accepted as an international standard, it can gain the upper hand in the global market, increase the possibility of market expansion, secure high international competitiveness, and increase imports through intellectual property such as patents. These reasons are in line with the establishment of the TSI, which integrates railway networks in Europe and continues to link and invest with the International Organisation for Standardization to gain an advantageous position in the world railway market. There have been several studies to reduce input costs, improve operational efficiency and stability in the railway sector, and provide wider market access (Morgan 1998, BTRE 2006). Morgan (1998) has proposed a three-step approach toward Europe's integrated railway system. According to his argument, first of all, the focus should be on eliminating different administrative barriers by country due to low cost and immediate benefits, and second, switching to multi-system railway vehicles so that railway vehicles can be used in different networks as well. He also argued that although it is costly, each country should focus on technically harmonizing railways. Research has been carried out from various perspectives to effectively operate these multi-step guidelines and to expect them to improve technology standardization and interoperability in the European railway sector (Maskus and Wilson 2001, ProductivityCommission 2009, Swann 2010). In addition, according to Holvad (2015), compliance with the TSI is generally achieved over a long period of time by replacing existing systems with new or expanded systems or infrastructure, especially mutual recognition and mutual acceptance of approved rail assets in one country, so that they can be used in another country without unnecessary time and cost loss due to repeated testing and evaluation. Thus, short-term measures are needed to reduce the costs and efforts involved in re-inspection through publication and comparative evaluation of technical rules among other countries, while increasing the transparency of the technology.

The role of the International Union of Railways (UIC) is mainly the standardization and improvement of qualifications for construction and operation of railways as international transportation systems, which aims to optimally meet the current and future challenges of mobility and sustainability development (UIC 2017). To keep step with the progress of innovation and development, UIC has reformed the standardisation process steadily and UIC solutions have been considered as a reference in various technical specifications in member states nowadays (Celia Levy, Simon Fletcher et al. 2019). This includes various tasks such as promoting world-class railway traffic, promoting interoperability, creating a new International Railway Solution (IRS) as a standard-setting body, Develop and promote all forms of international cooperation among members, promote sharing of best practices (benchmarking), and support members in their efforts to develop new business and areas of activity, proposing new ways to improve technology and environment, improving the solutions of competitiveness, reducing costs (UIC 2017). Among these tasks, understand the business demands in the railway community, develop the innovative programmes for identifying the solutions, prepare and publish the IRS document which aims to promote the realisation of innovative solutions are the most important tasks because they are related to the standardisation of railway technologies and systems (UIC 2017). In addition, UIC publishes the UIC leaflet which is the report of railway technology, and based on this, by adding various R&D experiences and accumulated data, UIC also publishes a huge amount of technical reports. These reports can be divided into three categories as Obligation (O), Recommendation (R), Information (I), based on the utilisation of railway technical standards, and these reports are the basis of technical standards which is a necessity in Europe such as TSI, EN (Baek 2015).

2.8 Chapter summary

In this chapter, as a preparation for the research, I studied various literature of communication and knowledge exchange, the main concepts to be addressed in the paper, as one of the innovation processes, and also looked at the studies related to the basic knowledge about it. The content consists of the Technology and Innovation Process, Knowledge and Learning Process, and Technology Transfer. In addition, the Multi-level Perspective Framework was introduced based on the network of the various institutions included in the case study.

As a result of the literature review, I was able to identify the importance of the network and the opinions of various scholars on the communication and knowledge transfer needed for the use of the network. Many scholars in the field of network and inter-organizational relationships have argued that the concept of knowledge exchange between companies is tightly linked to the innovation process. It is because innovation is often a complex and uncertain process, so the role of various external resources in cross-organizational collaboration is important (Iacono, Martinez et al. 2012). Also, these arguments have shifted increasing innovation research from a single innovator to a network of actors (Van de Ven 2005). Considering that cooperation includes intentional partnerships which can continue to exchange, share, and co-develop new services, products and technologies, high levels of collaboration will help build more innovative companies and this innovation will be primarily externally stimulated (Iacono, Martinez et al. 2012).

These studies are in line with the two of central literature in my research such as deepening network relationships can lead to more important responsibilities and more thorough knowledge sharing, and developing broader interaction capabilities can better communicate complex knowledge (Powell and Grodal 2005), and knowledge management of innovation is the most fundamental and most important part, in which various actors stimulate each other, share knowledge, skills, and experience, and influence each other (Malerba 2004), have helped to emphasize the importance of network building and communication system management. In addition, it was found to be related to the role and relationship analysis of various external actors that MLP can explain.

However, I can found that there have not been many cases in which networks have been studied, focusing on communication and knowledge exchange against the backdrop of the technology certification testing industry of SMEs. This forms the core of the practice gap of this research – where there is not enough research to help inform practice. This is better understood as a knowledge gap in standard research language, where I think that filling in the identified knowledge gap can produce a lot of benefits to related organisations. This is because, internationally, the test and certification market continues to grow at a high rate, and developed countries abroad are striving to strengthen their national competitiveness in certification projects using various sanctions. Therefore, the budget scale of overseas standard certification acquisition support projects has been expanded every year, with the assessment that they contribute significantly to promoting small and medium-sized enterprises in Korea. Also, KTL, which has been selected as a project management institution to support overseas standard certification acquisition, has made considerable efforts to support the national project effectively.

As part of its role, KTL conducted overseas technical tests for SMEs twice in 2018 and 2019, intending to develop and test a more effective communication and knowledge exchange system, along with successful test support in supporting overseas technology certification tests. This study aims to help meet the KTL's testing purpose, namely, network development and communication system verification to utilise supports for overseas technical certification tests. Also, by studying how various actors at various levels interact, create and develop networks through the actual testing process, I hope to provide useful insights to KTL and many organisations that prepare and support local and international technical certification tests. Using these cases to conduct the research can be determined that one part of the knowledge gap could be filled.

3. Research design and Methodology

According to Creswell (2003), researchers should have well-designed methodological ideas from a general philosophical standpoint on specific data collection and analysis procedures when planning a research project. This chapter describes the basis for this study design, especially the need for case studies. It also describes the research methods for collecting and analysing data. This study aims to understand the technological development and transformation of the Korean railway industry and seek future research directions. It requires a multifaceted understanding of technology development, conversion process and prominent actors' activities in the industry.

The concepts examined in the literature review are the innovation processes that focus on technological innovation, the acquirement of knowledge, the MLP, which is to be used as an analytical tool, the railway industry and railway technology. There have been many studies showing that MLP is very useful in explaining the behaviour and relationship of actors involved in various kinds of studies, but it has not been long since this model was introduced and actively studied. While there have been many studies explaining actors' behaviour and relationship at three levels in various fields, there has been a lack of research comparing the communication and knowledge exchange processes between organisations when one agency repeats the same content (here are two tests of SB's railway technology). Furthermore, many papers use MLP and technology transfer, but a lack of research can be seen in the part where the results of the changes in the communication system are explained using the MLP framework. Although the communication and network of different actors at different levels are described thoroughly, it is also important to check how changes in communication methods with the same relevant actors can be made when the same performances are processed repeatedly. Thus, when the organiser (in this research, KTL is the central actor for research) meet different organisations, although the setting is almost the same, observing what activities have taken place in terms of communication and knowledge exchange, what problems have occurred, and how the problems have been solved are helpful to check when developing the communication and knowledge exchange model for the future work. It also can contribute to the development of a network between organisations that collaborate. The study sought to confirm the following by examining the actual cases carried out on two occasions.

- Under similar conditions, acts of communication and knowledge exchange conducted with the same purpose are greatly affected by changes in the environment. In this environment, language, geography, and organisational and cultural environments play a major role. However, the impact of organisational culture may have more impact on communication and knowledge exchange than other factors.

- Communication, knowledge sharing and leading in networks are important for building innovation processes, and understanding organisational culture is an effective way to do this. Understanding organisational culture is also key to improving corporate competitiveness as it positively impacts the formation of interests.

3.1 Research Design

The cases used for this research are related to overseas technology certification tests conducted by KTL in 2018 and 2019. Having been able to participate in projects related to the Korean railroad industry, I had a connection with KTL, which gave me a chance to access two test cases. Data on the test's background and the process can be collected using participants' interviews and data received from the laboratory during the test (test details, results, schedule). Primary data on KTL are collected through online resources such as its websites and government-related agency description sites, and the test-related documents provided by KTL participants. Contact for interview schedule and interim confirmation was conducted through telephone, e-mails, virtual meetings, and face-to-face meetings throughout the business trips.

A research design is the set or framework of methods and procedures for collecting and analysing data or problems of research. Given this study's qualitative nature, a qualitative design method has been chosen as the basic framework. Quantitative research is a study conducted using data that can be quantified in numbers and has the advantage of securing the objectivity of research results through quantitative statistical analysis, while it has the disadvantage that superficial studies are likely to be presented. Moreover, qualitative research is analytical and fundamentally requires observation and explanation. It is impossible to define exactly which factors are important, therefore, it uses the approach that the factors which need to be analysed should be considered and interpreted by looking at the interactions of different components in the context in which they belong (Ochieng 2009). So, this approach that is trying to understand as a whole is very appropriate for this study. This is because, in the context of each of the agencies involved, the relationship with other institutions should be examined together. Although qualitative research has the disadvantage of lacking objectivity in research results due to its heavy reliance on subjective judgments by researchers, on the contrary, it has the advantage of being able to present in-depth research results (Creswell 2003).

Among these two research methodologies, it is determined that qualitative research methods are appropriate, given that the two test processes covered in this study are mainly conducted by the observation, exploration and understanding of the researchers. It is also because understanding the reasons, opinions, and motivations for a phenomenon (in the cases, the various interactions found during the testing process) becomes the basis of research. The qualitative approach following the tradition of phenomenological and analytical exploration was chosen as a methodology because it is more necessary to observe and interpret the actions of the actors observed in the test, verify the content through in-depth interviews with those involved to verify the interpretation of the researchers. Among them, in case studies introduced as a qualitative research technique, data is collected using participatory observations and interviews, and in-depth interviews are used to supplement possible problems in the objectivity and reliability of research due to researchers' subjective judgment in data technology and analysis. Both quantitative and qualitative methodologies were taken into consideration, and the reasons behind using a qualitative methodology are shown in Table 7.

Table 7 Comparison of Methodologies

	Quantitative	Qualitative
Methods of data collection	Questionnaire (distributed to a sample of people)	Interview, observation, literature, cases
Key Characteristics	• Data can be measured and quantified. • Quantitative research aims to build a complete understanding of reality using scientific methods. • Statistical analysis can be used to evaluate findings. • Quantitative research highlights trends in datasets but not the motivations behind observed behaviour (Goertzen 2017).	• Qualitative research usually relies on induction inference processes to interpret and structure the meaning derived from the data. • Qualitative research often focuses on discovering how people think and feel than determining whether thoughts and feelings are valid (Thorne 2000). • Provide insight into why people think, feel, or act in specific ways (Goertzen 2017).
Reason of use/unused in this study	• It is not easy to show proper communication and relationships between participants during the testing process. • This study does not show actual testing results, which can be analysed and presented using numbers and statistical charts.	• Participants of testing are mainly senior-managers level, with a limited number of participants. • It can present in-depth research results. • It is a methodology that is more interested in the process than in the results, so it is suitable for this study.

First, to explain technology development and transfer in the context of innovation, the literature review presents a basic understanding of the innovation process and the knowledge and learning needed. After understanding this, an understanding of the models and railway technology of the technical warfare was made, and the primary learning of the MLP framework to be used in the analysis was conducted. Prior to entering this case study, preliminary research was conducted on the structure and flow of the railway industry in Europe and Korea, and later in Chapter 5, the KTL and railway technology testing cases, focusing on the research on the role of the institution, is introduced, to find out the relationship between KTL and other actors involved in the advancement of Korean railway technology into overseas markets. In Chapter 6, the selected analysis tools were used to explain the findings, including the cases of various organisations' relationships and behaviours during the testing process. Chapter 7 discusses conclusions and the possibility of further research. Through this process, the study focuses on investigating how KTL and a wide range of actors interact and combine knowledge to create or supplement practices, processes and systems.

3.2 Research Questions

According to Flick (2018), designing research projects generally begins with writing research questions, and organizing them well helps design research, select data collection methods, and accurately shape data analysis and interpretation.

To study technology developments and transitions in the railway industry more deeply, KTL is selected to conduct the research. The reason for choosing this organisation is that it is a commissioned executive quasi-government agency, one of the most important Korean railway industry actors. It is also directly associated with the technology development and implementation processes and has many associations with various technology-related policies. The agency also has relationships with many foreign organisations, such as helping patents related to the railway industry. Therefore, it has the advantage of being able to study not only conduct technology development activities, but also the interaction with foreign institutions as well as others of Korea.

Taking Korea Technology Laboratory (KTL) as the case study, with the Multi-Level Perspective (MLP) as an analysis method, this study aims to investigate the technology developments and transitions of the Korean railway industry. By doing so, this study should enhance our understanding of the importance of technology developments and transitions in the railway industry for enhancing competitiveness in the global world. With this aim, the overall research question is,

How did KTL influence railway technology developments through collaboration with overseas agencies?

This research question includes the two sub-questions as follows:

- What role has KTL been playing in technological innovation in the Korean railway industry?
- What role does KTL play in advancing Korean railroad technology into overseas markets?

By studying this, the study seeks to enhance the railway industry's understanding and provide insight into the mechanisms through various actors. In terms of competitive technology development and proliferation of system-building efforts, by studying the achievements that KTL has made so far and by identifying what efforts KTL is making to interact among the various actors involved and how the interaction can affect both the innovation process and its systems, the critical role of KTL in the Korean railway industry can be ascertained.

A variety of factors has influenced the conduct of this research. After deciding on this study’s general field, the first step is to examine relevant prior knowledge regarding technology transition and the railway industry. This understanding of the nature and characteristics of the innovative technology transition process is connected with the railway industry's selected industry. A preliminary study is established based on various literature on technology innovation and transition and introduces the MLP framework, which will be used as an analysing method for the actors’ collaborative networks. The case study is selected carefully to enrich the understanding of the Korean railway industry's technology development and transition process. For a clear understanding, the empirical part includes studying the agencies and organisations related to the Korean railway industry's technological area. The initial approach to the empirical research field involves attendance at KTL. Qualitative data is collected via a wide exploration of document sources, interviews, and observation.

3.3 Data collection and analysis methods

The data collection method is as follows. Firstly, this paper investigates the Korean railway industry's background and development process through literature, news, and railway-related bibliographies. Also, I use published papers on the MLP which is chosen as the method of analysis. For the KTL case study, interviews with related experts are included as well as basic data collection. Griffee (2005) outlined that considerations for using the interview include determining the interviewee and the interview location, determining the interview questionnaires content, and choosing when to stop the interview and how to collect data, if necessary. Considering all of this, the interview was planned and conducted. In this study, the interview is a very useful way to collect qualitative research data. This is because the more detailed experience of the test results and processes already experienced by the key stakeholders involved is in line with the study's tendency to focus on understanding the relationship.

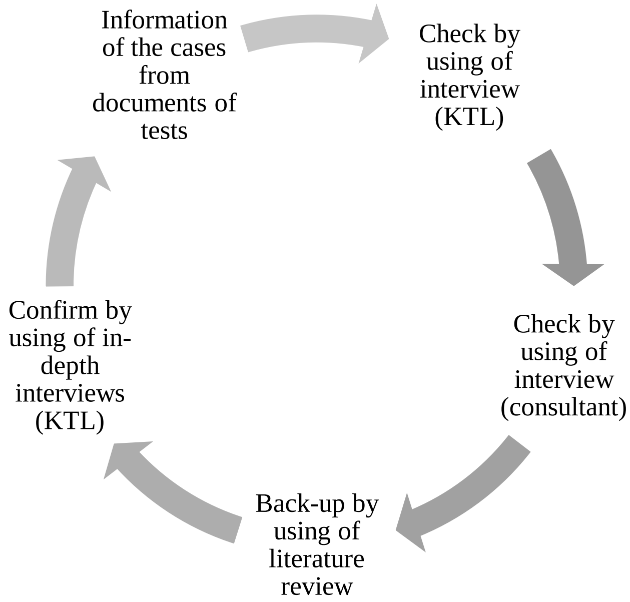

Figure 9 The process of data collection and analysis of the research

The data collection and analysis process is as shown in Figure 9. Based on the documents recording the test process, the information about the test was investigated, and the interview was conducted on the parts unknown from the document during the process. At this time, researchers who participated in the test and consultants in charge of relations with overseas laboratories were interviewed. This was because they knew the most about the test. Since KTL is the organisation that can provide the most accurate information for research, and the consultant played a given role in both the communication systems of both KTL and overseas laboratories, it was essential and also a very effective way to interview them and verify the data. After completing the basic data survey and verification, the theoretical part of the case study and analysis was to support the contents theoretically using the contents learned in chapters 2 and 4. Further details to be confirmed were reinforced by an interview with the required agency.

As claimed by Flinders (1997), although interviewers may not be able to say exactly what they think, and may not get the information they want because they may not have the opinions they need, in order to overcome this, the study conducted in-depth interviews with selected people, who are precisely involved in the event, and tried to minimise these limitations by using the data together in the reference, at the same time. The interview questions used at each stage of the case study can be classified as shown in Figure 10. The coloured areas at each stage are the areas that I want to focus on in this study, as they are heavily involved in the degree and effectiveness of the relationships and communications of each agency using the MLP framework.

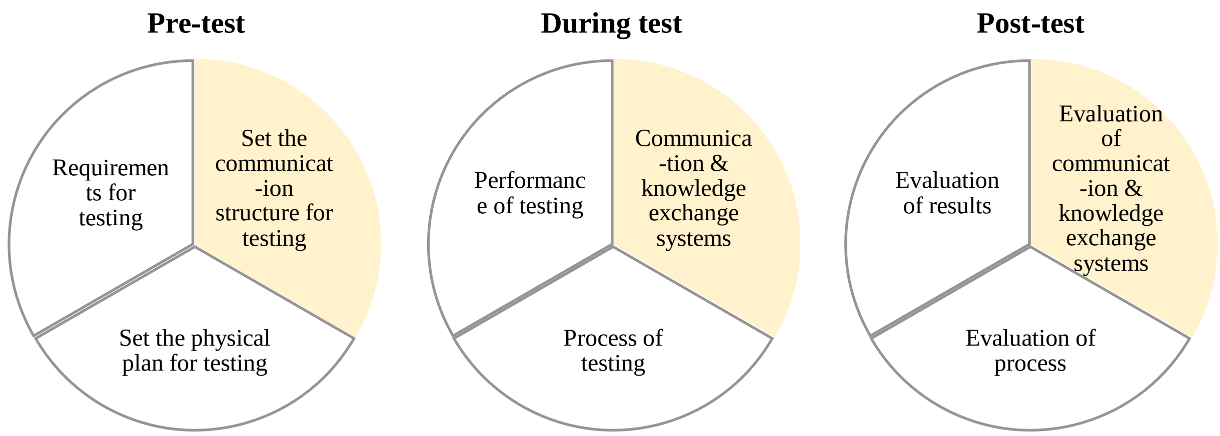

Figure 10 Classification of interview content used at each stage of the case study

For analysing the relationship of the cooperation system of the testing, I choose the multi-level perspective framework. The MLP framework describes innovation processes as a result of interactions between actors at multi-levels. I saw that KTL, chosen as the centre of case studies, is able to connect niche-level and regime-level because it supports the development of new technologies and makes them mainstream in the Korean railway industry. Therefore, I am confident that the MLP framework, which demonstrates the importance of interrelationships and relationships at different levels, can be used effectively in analysing the role of KTL from this perspective. By studying the MLP framework at various stages of the case study in the technology accreditation test, which is the main focus of this study, the role and importance of KTL can be confirmed its position and importance as an organisation related to technology development and transition. It is also possible to see how the MLP framework can be validated as an analytical method.

Regarding the findings of the test, the company conducted in-depth and continuous interviews with key participants of the KTL and consultants in charge of contacting overseas institutions to confirm each part. Interviews with major participants were actively utilised to analyse the actions and results of organisations on communication systems and knowledge exchange. Among them, the main contents of the interview were attached to the appendix.

4. A Preliminary Conceptual Framework

4.1 Understanding of the Railway Industry

From an administrative point of view, the national railway system can be considered a business that involves multiple products/services and regions. First, to explain the aspects of multiple product/service businesses, products and services are transportation, and the three main markets are passengers, parcels and freight (Casson 2004). The three main markets include: 1) passenger transport for travel, leisure, and commuting, 2) parcel transport for transportation of mail and parcels, 3) freight transport for industrial materials such as coal and minerals, container transport of general products, etc. Secondly, within one national railway system, it is a business to connect multiple headquarters and regions. The moving of raw materials to local power plants or taking passengers to different locations is a local business whilst moving passengers and cargo from provincial areas to large cities is a more metropolitan business undertaking connecting regions (Casson 2004, Casson 2009).

Similarly, the railway industry can be considered as an important industry sector due to the following reasons (Lee 2005). According to Lee (2005), the railway is a transportation method that can solve traffic problems by enabling mass transportation through its environment-friendly methods. Also, the low energy consumption of railway transportation can contribute to the national economy. Moreover, it can play a role in public transportation as a national key industry and serve as a driving force of economic development, which plays a major role in enhancing national competitiveness. Although there are some differences between countries, railways are efficient means of transportation that contribute to the policy of curbing global warmings, such as linking cities to cities and low carbon emissions, in terms of stability and economic impacts (Cho, Jeong et al. 2017).

Furthermore, the railway system is a large and complex sociotechnical system (Wilson, Farrington-Darby et al. 2007). Therefore, it is clear that people become the centre of railway activity, starting with planning, creating networks about facilities and operations. People connect with people, tasks, software, the environment, and so on. Due to essential connections such as these, people need to work together to ensure that the system works smoothly in a variety of environments, such as political, legal, social, technical, and economic, with many factors affecting the railway system as in Figure 11.

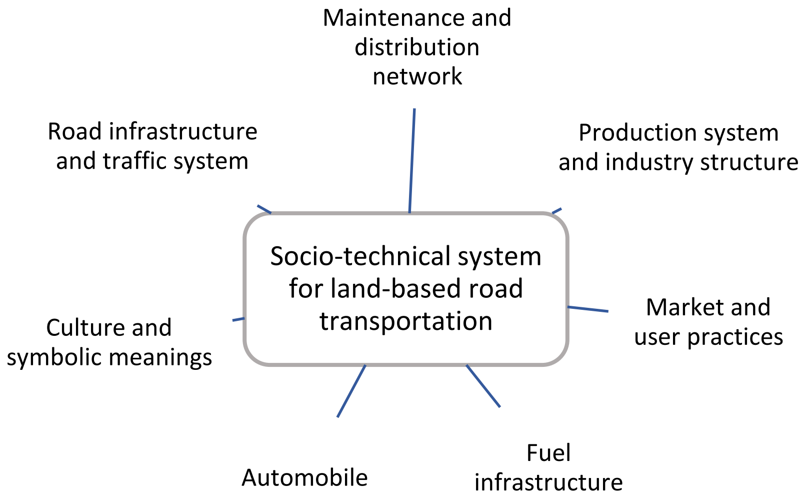

Figure 11 Socio-technical system for modern car-based transportation (Geels 2005)

Traditionally, the transportation industry has been a widely regulated sector that has been owned generally by the government. Also, like any other public industry, it was the subject of privatisation or broad government regulation. However, in recent decades, there has been a steady deregulation process in telephone, gas and water supply. The transportation industry is no exception. Railway transportation changed more slowly. Originally, a monopoly regulated in a monopolistic field, it has begun to change in recent years (Savignat and Nash 1999). Western countries nationalised early these major national key industries such as electricity, telecommunications, roads, ports, and railways. These kinds of industries need a huge amount of initial input, therefore nationalisation in these industries was a natural choice for public interests. However, as the times have changed, major national key industries have become privatised. It is the way to prevent inefficiency which could bring from the monopoly that due to state-owned enterprises' trying to monopolise the industry and restrict competition. These European railway industry structure reforms are divided into the following three types: the first is a way to completely separate facilities and operations, the second is a way of operating the main powers. And the third is a way of establishing holding companies (Campos and Cantos 2000).

By looking at railway market structures in three European countries, Britain, Sweden and Germany as shown in Table 8, Jung and Chang (2014) identified the above structural reform types, which are somewhat different from how privatisation and competition systems are introduced, but the direction of structural reform in the railway industry, which is all vertical and competitive, is that the state bears the fixed costs of infrastructure construction and service management. This laid the structural foundation for enhancing the competition in the railway service sector. Second, the railroad service market, maintenance and vehicle rental market were divided to reduce the burden on railway service businesses. This will also reduce burial costs to increase competition in the railway service market. Third, it avoided monopolistic operation by a specific company and induced competition by bidding for operating business rights. Profit lines are the maximum user fee, and deficit routes are making competitive bids with the lowest subsidy, improving efficiency while fulfilling their obligation to provide public services.

Table 8 Structure of the rail industry in three European countries (Jung and Chang 2014)

<table>
<tr><th colspan="2"></th><th>UK</th><th>Sweden</th><th>Germany</th></tr>
<tr><td rowspan="2">Restructuring</td><td>Infrastructure</td><td>Private sector</td><td>Public sector</td><td>Public sector</td></tr>
<tr><td>Services</td><td>Private sector</td><td>Public-Private Partnership</td><td>Public-Private Partnership</td></tr>
<tr><td colspan="2">Competition</td><td>Privatisation, Competitive tendering for the entire tracks</td><td>Remained as a publicly owned company, Competitive tendering for selective tracks</td><td>Competitive tendering for selective tracks, Competitive tendering for selective tracks</td></tr>
</table>

In this study, I took a closer look at the case of Britain, which has undergone several rounds of nationalisation and privatisation, and has implemented structural reforms for railway development.

4.1.1 The UK rail industry

From 1760 to 1830 in England, the development of various industries took place. Various kinds of innovations in agriculture, transport, industry, commerce, finance, including the progress of urbanisation and the distribution of factories, a transformation of transportation institutions, such as roads, canals, iron rails, regular steam lines, etc. and the development of new sources of raw materials, development of new markets, and the invention of new commercial means have taken place, and the beginning of railways has emerged amid this (Kim 2006). After many early studies, the steam locomotive invented by G Stevenson was unveiled in London in 1814 which was a huge success because of its speed and efficiency, and the construction of the railway between Stockton and Darlington began in 1821 (Cottrell and Ottley 1975, Song 2004). From the early 1820s, when British trade was brisk, new technologies such as mobile steam engines and railway construction technology brought the possibility of new transportation (Arnold and McCartney 2005). In 1825 the Locomotion, built at Stevenson's locomotive plant, completed the test drive (Andrews 2014). Moreover, in 1830, the Liverpool and Manchester Railways, called 'the world's first railway', was opened (Kim 2006). According to Bagwell (1988), Liverpool and Manchester Railways show two important aspects: first, it was fully operated by steam locomotive power from the beginning of the operation. Second, it was managed and operated exclusively by a company equipped with all the provisions for the transport of goods and passengers. At this time, there was no significant need for support from the central government, nor did the government think of taxing the potentially enormous cost of railways (Arnold and McCartney 2005). Instead, 'public-private' finance combinations were used to support the parts of the road and port system at the regional level (Bagwell 1988, Freeman and Aldcroft 1991). Since then, the railway network has spread rapidly across Britain. At this time, most of the all basic rail networks in England were completed and it led to the railway construction plan for the second half of the 19th century (Bagwell 1988). Due to the influence of the British railway industry, all the funds, rails, locomotives and construction engineers needed to build the early railways were dependent on the United Kingdom, and later British technology was expanded to Asia via Europe (Lee 1999). The railway opening year of some countries is shown in Table 9.

Table 9 The year of railway opening (Lee 1999)

Country	Year	Country	Year	Country	Year
UK	1825	GERMAN	1835	JAPAN	1872
USA	1830	RUSSIA	1838	CHINA	1877
FRANCE	1832	ITALY	1839	KOREA	1899

In the early days of railway construction, the government did not play a direct role. The railway industry in the UK was started entirely by private enterprises and there was no national support. The state permitted to build railways to private companies that were reviewed and approved by the private railway construction plan and granted a patent. The railway construction was pushed by a private company to pursue profits to any extent. The railroad company was established under the leadership of stakeholders and industrialists which was a form of investment by various people (Kim 2006). Therefore, operations were not planned and were less efficient. As a result, the railway integration movement took place from the 1840s as a result of numerous railroad companies' unlimited pressure for railway construction by their respective plans (Kim 2006).

The railway was large in capital from the start, so it had to develop a new management organisation. The railway company, which required a huge amount of capital, started as a company in the form of a corporation from the beginning, and the enterprise integration movement was launched from the beginning. According to Gourvish (1980), In 1914, a large number of railroad files were compiled, and later, when the war broke out, the railway industry was placed under the management of the Government's Railway Executive Committee, and numerous companies were merged. Since 1923, it has been merged except for some private railways, and four railroad companies, which are London Northwestern Railway, Midland Railway, Great Western Railway, and North Eastern Railway, have been formed (Gourvish 1980). In the intensifying competition, the leading rail companies are seeking to consolidate small and medium-sized rail companies and directly control them under a single system (Kim 2006). Arnold and McCartney (2005) stated that this shows the beginning of the reorganisation of the 1948 nationalisation. Thus, large enterprises faced a new challenge such as management organisation, so they worked to manage modern enterprise management through the development of an institutional framework for their management, introduction of professional and organisational management, and comprehensive understanding of complex accounting operations (Gourvish 1980). After World War II, in 1947, nationalised industries were carried out including railways, and four private railway companies were integrated and refurbished under the name British Railways (Gourvish 1980). Since then, when the nationalisation of the major core industries failed to succeed and brought about a sustained recession, the British government enacted the Railroad Act to clarify the role of railways, make efforts to expand investment, and reform the organisation to productivity units by introducing commercialism, however, did not achieve much. This was due to low productivity from state operations, inadequate investment, inefficiency in management and irregular financial support (Yang 2001). Thus, in 1994, it returned to the early shape of the 19th century British Railways, which were privatised by more than 30 private passenger rail companies to improve the quality of railway transport services and reduce losses. The privatisation of British railways began in earnest in 1996 (Yang 2001).

After many trials and errors, the government focused on the railway industry and infrastructure restoration to take over the company, and Network Rail, which was established under a government guarantee, managed the railway infrastructure (Jupe 2011). Network Rail has established a five-year railway infrastructure development plan which is called Network Railway Control Period (CP), and under this plan Network Rail has consistently carried out infrastructure improvement projects (Gibson, Cooper et al. 2002). This steady investment and improvement in the management system have led Britain once again to establish a safe railway system (Powrie 2014). Since then, Britain has accepted and used the EU's railway regulations, while presenting and implementing various long-term and detailed action plans for railways in terms of comprehensive transportation policy. Table 10 outlines the changes in railway policy during the period, and Table 11 shows the change in the regulations and laws of the rail industry in the UK after privatisation.

Table 10 Policies in the UK Rail Industry between 1948 and 2008 (Lee and Chung 2010)

Year	Party	Prime Minister	Major Legislation	Major Policy
1947	Labour	Clement Attlee	Transport Act 1948	• Nationalisation of all land transport

(1945-1951)				• Management at the British Transportation Committee (BTC)
1953 (1951-1955)	Conservative	Sir Winston Churchill		• Deregulation • Enhancement of the Market Function of Cargo Transport
1962 (1957-1963)	Conservative	Harold Macmillan		• The abolition of the Transportation Committee • The abolition of the deficit line
1968 (1964-1970)	Labour	Harold Wilson		• A culture of public assistance • The railroad corporation is in charge of transportation only. • Induction of Long-Range Cargo to Railway Use
1974 (1974-1976)	Labour	Harold Wilson	Transport Act 1974	• Clarification of railway role • An increase in railway subsidies • The establishment of a new railway freight subsidy
1979 (1979-1990)	Conservative	Margaret Thatcher	• Transport Act 1980 • Transport Act 1985	• Deregulation • Decommissioning the National Cargo Corporation
1993 (1991-1997)	Conservative	John Major	• New Opportunity for the Railways (1992) • Transport Act 1993	• The separation of the top and bottom of railway folk movies • Competition Bidding and Introduction of Railway Supervision Authority
1997 (1997-2004)	Labour	Tony Blair	• A New Deal for Transport (1998) • Transport Act 2000 • Transport 2010 (2000) • Future of Railway (2004)	• Installing the Strategic Rail Network Authority (SRA) • Eliminated SRAs and transferred functions to the Transportation Department in 2004.

2005-2008	Labour	Gordon Brown	• Railway Act 92005) • The Railway Infrastructure (Access and Management) Regulation (2006), • Railway (Interoperability) Regulation (2006), • Railways and Other Guided Transport Systems (Safety) Regulation (2006), • Delivering a Sustainable Railway (2007)	• The internationalisation of railways • The solution to environmental problems • Presenting the vision of comprehensive transportation policy

Table 11 UK Rail Industry Regulation after Privatisation (Lee and Chung 2010)

	At the time of privatisation (1994)	Change 1	Change 2 (1995)	Since 2006	Note (Trends)
Franchise management	OPRAF	SRA (2001)	DfT (2005)	DfT	-
Infrastructure ownership and management	Railtrack	Network Rail (2002): the non-profit corporation	RAIB (2005), Network Rail (2005), ORR (2005)	-	-
Safety	HSE	RSSB (2003)	RAIB (2005), Network Rail (2005),	ROGS (Safety) Regulation (2006) added	EU law applies to the British Rail Act

			ORR (2005)		
Regulatory function	ORR	-	-	-	EU law applies to the British Rail Act
Planning Functions	-	SRA (2001)	DfT (2005)	Delivering a Suatainable Railway (2007)	Government-led long-term investment plan in place (2007)

RAIB: Rail Accident Investigation Branch

RSSB: Rail Safety and Standard Board

DfT: Department for Transport

4.1.2 The Korean railway industry

Korea's railway history began with the opening of the Gyeongin Line in September 1899 (ROTECO 1999), much later than Britain (1825), the United States (1830), and Japan (1872). Korea's railway industry initially saw Western railways and felt the need, began through contact with the U.S. and French companies with the support of King Gojong. At this time (initially), American steam locomotives were imported and introduced. The first locomotive was built in Korea in 1927. However, under Japanese colonial rule, Japan took over all of the facilities, installed and opened them. It was used as a means of transportation for Japan to advance to the continent and seize the Korean Peninsula's assets. In 1945, the first locomotive made by Korean technology appeared, and it was only in the 1960s that the era of modernisation was faced when diesel locomotives were introduced and operated in 1964. After liberation from the Japanese colonial era, the U.S. Military Government was in charge of the railroad administration south of the 38th parallel. During the Korean War, the right to operate was transferred to the U.N. military until 1955. Since then, the U.S. has steadily introduced diesel locomotives. In the 1970s, when railways began to emerge as the main artery of industrialisation in the era of mass transportation, the passenger transportation of railways remained in the 25% range, and 52% of cargo transportation was shared by railways. The railway grew and developed in the automobile sector and all areas such as facilities, electricity, and operation. In 1972, electric locomotives were introduced, and in 1974, subways in Seoul were opened. In the 1980s, there was a discussion on the government's high-speed railway, resulting in a plan to build a high-speed train was established in 1989. From this time on, Hyundai will assemble and produce Korean diesel-electric locomotives in partnership with U.S. technology. Soon after, the Gyeongbu Express Railway's construction plan was announced in 1990, followed by the Gyeongbu Express Railway opening on April 1, 2004, entering the era of the high-speed railway, a symbol of transportation revolution in the 21st century (Railroad 1999).

Such development of the Korean railway industry can be explained by the development of the Korean economy. The Republic of Korea's economic growth has been remarkable. Right after the Korean War, Korea was one of the poorest countries. However, in the following several decades, by structural transformation and productivity improvements, Korea has been shown considerable achievement in an economy mainly engineered by the industry sector (Jeong 2020). In particular, Korea has taken economic growth strategies through exports, as exports to overseas markets were necessary because the domestic market was narrow. Korea's economic development process is characterized by 1) a nationalistic political culture, 2) a leading conglomerate-oriented economic development policy, and 3) active participation in international exchanges due to the need to adopt open-door policies. (Kyong-Dong 2010). The Korean government faces changing the Korean economy from export-oriented manufacturing to a sustainable economy related to creativity and innovation (Jung 2020). In this regard, upgrading industrial capacity and international competitiveness in manufacturing would be the most effective way. This study can be considered as one of the efforts to help this upgrading work.

In this process of economic development, Korea's railroad industry has also made eye-opening progress. Rail transportation has characteristics such as mass transportability, timeliness, and stability. Also, it has advantages in terms of environmental friendliness, energy efficiency, and land-use efficiency which are important nowadays (Lee and Cho 2012). Moreover, because it takes a large amount of capital as well as many resources, generally the government runs a rail industry business, rather than leaving it to the market and Korea is including this case (Kim 1999). Railways in Europe and many other countries have traditionally been organized as legal monopolies, a method controlled by regulators with authority to influence organisation, price and market entry within the domain to which the monopolist applies (Jensen 1998).

However, in many countries, problems arising from the nationalisation of the rail industry. The main point of the problems surrounding this railway industry is the inefficiency and naïve operation of public institutions. Therefore, the privatisation of the OECD countries has become a trend, which is one of the solutions to the operation of public institutions that provide public services, so that the private sector can manage the area that the government has operated. (Kim 2005). Also, a privately commissioned management system that entrusted the government to conduct the private sector affairs has been introduced (Lee and Kim 2015). Such privatisation and the introduction of private trust systems are effective methods for the vitality of the economy, but they also have some problems. In the case of privatisation, public service provision's stability can be degraded, and private companies may again become monopolised. Also, in the case of the privately commissioned management system, there is a possibility of degradation of service quality due to the lack of competitive structure. Therefore, countries such as the UK and Japan have considered participating in public and private sectors in public bidding together to select public service providers (Kim 2012).

According to Jung and Chang (2014), there are two types of monopolistic markets in the rail industry. The first is the monopoly of the rail infrastructure market. Generally, public services such as the rail industry require large-scaled facility investment because of the nature of itself, and in most cases, the industry provides products and services through the network. Moreover, as production volume and output increase, the average production costs decrease in the long term. In this situation, choosing one company to produce and supply products and services has been seen as a more efficient way than share the role with many companies. This is called a natural monopoly and this is the type of rail infrastructure market (Lee and Chae 2001). Natural monopoly theory explains the market in which only one place can produce it for structural reasons, which is characterized by how much the cost of production can be reduced if performed only by one institution and the degree of its sustainability (Mosca 2008). The second is the monopoly of the rail service market. For example, when a company owns a railroad service, the rail service market is automatically in a monopoly state (Jung and Chang 2014). Usually, compared with competitive markets, monopolistic markets are more prone to fail in the form of degradation of product and service quality, economic loss and violation of public service. Therefore, when the rail industry needs to be reformed, one of the main goals is solving the problems of monopolistic markets. Thus, the government can consider several management plans, including promoting competition in the market, regulating the activities of monopoly, converting monopoly to state ownership, and leaving it as it is. Because these plans have different strengths and weaknesses, they should be implemented following the market characteristics (Gans, King et al. 2011).

Railway transportation has a lot of advantages such as safeness, dispatch reliability, energy efficiency, and economic feasibility, therefore, many policies which focusing on rail transit have been established and promoted in relation to improving its sharing of passenger and freight transportation. In developed countries such as Europe, the policies focusing on rail transit for transport demand for transport demand through promoting environmentally friendly transportation that was heavily increased have been fuelled by the government since the 1990s. Especially, with the commencement of a new paradigm called sustainable development, the transportation policy has been shifted to the railway-based traffic system to maintain the environment and quality of life (Yong-Ki 2010). These policies' main aim is to make railway transportation become more attractive and competitive transportation compared with other forms of transportation (Yang 2012). The rail-centred transportation system is a convenient system that can use full of advantages such as speediness, mass transportation, timeliness, eco-friendliness and reliability. Therefore, it is needed to reorganise the regional transportation system that connects the major cities, and the traffic system within the city also needs to construct a rail-centred by getting out of the road-centred transport system (Yong-Ki 2010). To do so, governments in many countries have been making huge efforts to increase the railway's competitiveness by making a considerable investment in the rail industry and implementing radical structural reformation of the operating system

(Yang 2012). In line with these changes, the Korean government established long-term investment plans for the railway network, such as ‘The plan for the key national traffic network (2000-2019)’ and ‘National Railroad Network Establishment Plan (2006 ~ 2019)’ (Yong-Ki 2010). In the 1990s, railway restructuring began in Europe (Cantos, Pastor et al. 2010). This was an effort to strengthen the competitiveness of the railway which was reduced compared to air and road transportation, although railway transportation is a mass transportation and environmentally friendly transportation (Lee and Yu 2009). Many countries considered the rail industry a natural monopoly industry directly operated by the public sector in almost every country, which is the main reason for the loss of competitiveness. To solve this problem, a method of separating the railway into the infrastructure for the construction and management of the railway, and the operation centred on train operation, which is called ‘vertical separation’ (Cantos, Pastor et al. 2010). The reason for the separation of the former Korean National Railroad into Korea Railroad (KORAIL) and Korea Rail Network Authority (KRNA) is the result of accepting it (Woo 2013).

The structural reformation of the rail industry has been taking place for more than ten years. Therefore, Lee and Kim (2015) suggested that policy changes caused by the interaction of various external variables and long-term policy actors. The Korean government has been put effort to explore the development of the rail industry and it can be found in government plans. The following are the important policies and plans of the Korean government for the development of the rail industry which has been established and carried out: The structural reformation of the rail industry in Korea can be divided into three phases according to its process; 1) before the implementation of structural reformation (before 2003), 2) preparation phase (in 2003), and 3) implementation phase (after 2004) as shown in Table 12 (MOLIT 2013).

Table 12 Major details of the railway industry structure reform by year (MOLIT 2013)

Classification	Schedule(year)	Key contents
Prior to the Implementation of Structural Reform	Before 2003	• Promised to push ahead with the railway public corporatisation in the event of a loan agreement with the World Bank ('80.3) • The Korea Railroad Act was enacted and the railway public corporatisation was promoted, but the Korea Railroad Act was repealed after two delays ('89-'95). • Determination of government policies on privatisation and public corporatisation of the railway (’99.3)

		• The Railroad Industry Development and Structural Reform Act and the Korea Railroad Corporation Act were submitted to the National Assembly ('01,12) • The Korea Railroad Corporation Act has been submitted to the National Assembly ('02.10)
Preparatory stage	2003	Institutional Preparation for Structural Reform • The policy direction is redefined based on consultation between related ministries and related experts and the railroad joint labour-management consultation ('03.4). • A revised bill related to the structural reform of the railway industry has been submitted (Basic Railroad Industry Act, Korea Railroad Corporation Act, Korea Railroad Corporation Act) ('03.6) • The Framework Act on the Development of the Railway Industry and the Korea Railroad Corporation Act were promulgated ('03.10) • Korea Railroad Act promulgated ('03.12)
Implementation stage	2004	• Separation of infrastructure and operations · Establishment of Korea Railroad Corporation ('04.1) · Handling of assets and liabilities of the Korean National Railroad • Open and separate facilities/operations of the high-speed railway · Handling High-Speed Rail Self and Debt • Preparation for the Establishment of Railroad Construction · Ministry of Construction and Transportation Securing Railway Policy Organisation · Promoting the readjustment of relevant laws
	2005	• Establishment of Korea Railroad ('04.1) • The railroad corporation's push for better management.
	Since 2006	• The Development of Competitive Railway Market Environment • Reviewing the Separation of Railway Passengers/Cargo

		• Performance evaluation and evaluation report for structural reform ('07~'08)

Also, related national plans have been made and implemented, among which the following are the Korean railway development plans under the government's supervision, as shown in Table 13 (KOTI 2004).

Table 13 Current status of the related plans for the basic railway industry development plan (KOTI 2004)

Field	Title	Department	Target period
Investment in railway facilities	Fourth National Territory Development Comprehensive Plan	MOLIT	2000-2020
	National Long-term Traffic Network Construction Plan	MOLIT	2000-2019
	Second Mid-term Transportation Facility Investment Plan	KTI	2005-2009
	A Study on the Revision and Revision of the Framework Plan for the Construction of the National Railroad Network in the 21st Century	KTI	~2020
	The Second Five-Year Plan for Metropolitan Transportation in the Seoul Metropolitan Area	MOLIT	2004-2008
	National Finance Management Plan	Ministry of Planning and Budget	2005-2009
Facility management	Railway Asset Processing Plan	MOLIT	2003-2005
railway operation	A Basic Plan for Structural Reform of Railway Industry	MOLIT	Since 2004
	Mid- to long-term railway management improvement plan	KORAIL	Since 2005
railway safety	Master Plan for Railway Safety Plan	MOLIT	2006-2010
	A Study on the Development of Railway Safety Technology	MOLIT	2004-2009
	5th Traffic Safety Master Plan	MOLIT	2002-2006

Technology Development	Mid- and Long-Term Plans for Research on Railway Technology Development	MOLIT	2000-2010
	National Transportation Technology Development Plan	MOLIT	
Etc.	National Logistics Basic Plan	MOLIT	2001-2020

Besides the UK, other counties in the EU also carried out the reformation of construction in order to secure the competitiveness of the rail industry, for example, Sweden implemented the separation the management of railway infrastructure and services through the vertical separation policy in 1989 (Cantos, Pastor et al. 2010). Additionally, in the 1990s, many other countries in the EU, such as UK, France, Netherlands, Denmark, Finland, Norway, and Portugal, had similar policies, while others including Austria, Greece, Belgium, Ireland, Swiss, Italy, and Poland push forward the integration of the management of infrastructure and services of railway industry by using of the vertical integration policy. Moreover, France, which is the vertical separation model of Korea, had shifted to an integrated structure of the management (by SNCF) and infrastructure (by RFF) in 2012 (Emmanuel and Crozet 2014).

The rail industry in Korea started as a form of government enterprise by the Korean National Railroad, separated from the Ministry of Transportation in 1963 for flexible operations and management (Lee 1999). Originally, until the 1970s, the Korean railway played a vital role as the central transportation. However, with the opening of the Gyeongbu Expressway, the road transportation era was started, the market share of the railway was decreased and deficit management has become firmly established since 1976 (MOLIT 2013). At that time, the rail industry was operated mainly by the Korean National Railroad and the deficit operation and debt accumulation have continued since the separation of facilities and operations (Lee and Kim 2015). In terms of management and operations, the biggest reason for the continued deficit and debt accumulation in the rail industry was inefficient management, excessive government regulation, and monopolistic market structure (Lee and Kim 2015).

In the 1980s, due to the influence of the foreign rail industry structural reformation policies, Korea started to reform the rail industry in 1993 after three years preparation period (Jung and Chang 2014, Lee and Kim 2015). To solve chronic rail industry problems, the government has made efforts for management improvement, however, there are a lot of limitations. Therefore, by agreeing to take over the railway loan from the World Bank (IBRD), the Korean government promised to turn the Korean National Railroad into public corporatisation (MOLIT 2013). Since then, the government enacted the Korean Railway Corporation Act in 1989 to promote public corporatisation. In 1993, the Korea Railroad Corporation was established to ensure autonomous management in all business areas, including the operation and construction of trains (Lee 2003). However, despite the enactment of the related governmental regulations, reformation of the structure was abolished in 1995 due to the opposition of the Korean National Railroad and railway unions as well as the lack of willpower of the government to carry on. In 1995, the special act on the operation of state railways was enacted which abolished public corporatisation system, and it is because of the financial burden and the lack of foundation of independent management (MOLEG 1995)

Since then, the management improvement of the Korean National Railroad has been promoted in the form of integrated railway facilities and operations with the nationalisation of the rail industry has been maintained. Also, as the continuous demand for structural reformation, the Korean National Railroad, the responsible administration organisation, set a five-year plan for improvement of management to achieve self-reliance with the finding the alternatives, including the contracting out some parts of government services (MOLIT 2013). Moreover, in 1999, the privatisation promotion committee was established within the Korean National Railroad to prepare the implementation plan for structural reformation, and the organisation was divided into the infrastructure division (integrating of High-speed rail construction) and the operation division (sale of private capital) (Lee and Kim 2015). In 2003, regulations related to the development and the structural reformation of the rail industry, such as the Act of the Development of Rail Industry, Korea Rail Network Authority Act, and Korea Railroad Corporation Act were established (Jung and Chang 2014). At last, with the abolishing of privatisation and the re-promoting of public corporatisation, the Korea Rail Network Authority which is responsible for rail infrastructure construction and management was established and in 2004, the Korean Railroad (KORAIL) which is responsible for the transportation of passengers and cargo in 2005, so that, the separation of the rail industry was achieved (Jung and Chang 2014). This structural reformation aims to strengthen the autonomous management and procurement of the publicity in the rail industry as can be seen in Figure 12 (MOLIT 2013).

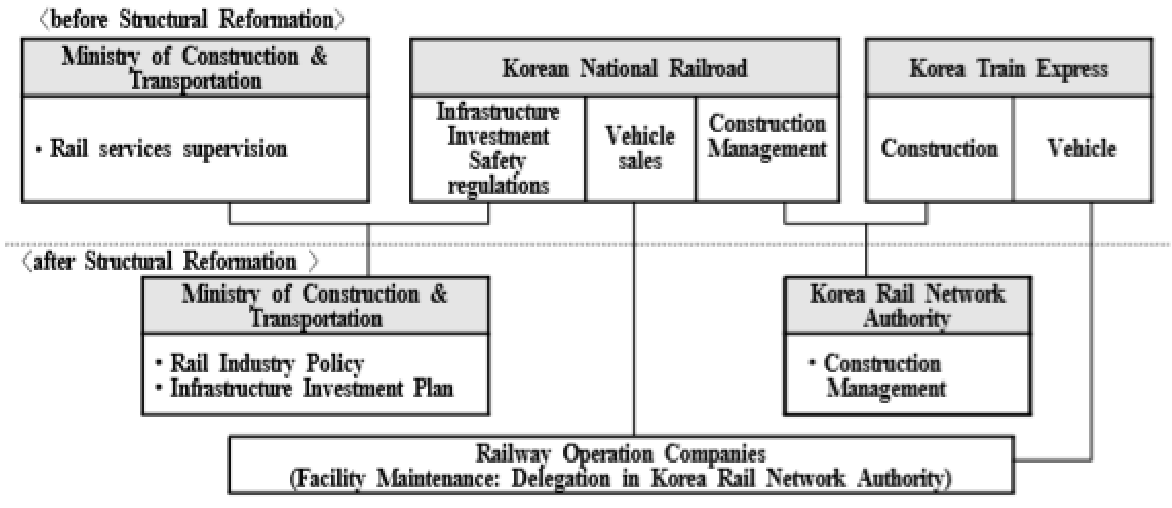

Figure 12 Structural reformation of rail industry of Korea in 2001 (MOLIT 2013)

Korea has been trying to build a foundation of resurgence the rail industry through structural reformation, which aims to enhance the railway's competitiveness by taking responsibility for the infrastructure investment in the government based on the principle of 'selection and concentration' (Lee 2004). According to Yang (2001), the following three directions have been promoted to enhance the competitiveness of railway transportation: 1) the direction to improve the competitiveness through internal management innovation by transforming the operating system from the governmental organisational system to the private management system, 2) the direction to improve the competitiveness through strengthening market functions by making appropriate internal competitiveness in the railway transportation system, 3) the direction to improve the competitiveness in railway transportation by creating fair competition in terms of transport policy level.

According to 'A Study on the Establishment of the Basic Plan for the Development of Railway Industry (Lee 2004)', the government has been made a plan to build an organisation to maximise revenues system, to increase revenues by enhancing business capability, and to reduce costs by managing human resources efficiently. To doing so, the following detailed plan was made to reform the structure: 1) for the transition to public organisations which are enterprise-typed, the government ensures management transparency and introduces self-regulatory management responsibility systems including management innovation, accounting separation, the slim structure of the organisation, and performance management, 2) for the efficient human resources management, keeping the working hour following Labour Standard Act, solving the increased businesses through reform of the operating system and outsourcing, 3) for the efforts of the increase of revenue and reduction of costs, building the management responsibility system, developing service in relation with other divisions, promoting recruit new customers, expanding rail freight transport capability and improving efficiency, and reducing the workforce by the relocation and redesign of work, 4) minimising the train service which shows any profitability, 5) allowing private participation in some lines, 6) providing institutional support, such as development and application of reward for public service obligation, reasonable adjustment of the user charge of rail facilities, supporting tax exemption and reduction, and giving relief of high-speed railroad construction debt, 7) harmonising with labour unions, 8) establishing a continuous plan for improvement of management and operating, etc (Lee 2004).

As for the structural reform of the nation's railway industry, the discussion began in 1998 with the start of the management diagnosis of the Korea Railroad Administration, and the government's decision on the privatisation of the operation sector and the industrialisation of the facility sector in 1999 and the conclusion of the basic plan for the structural reform of the railway industry in 2001. However, the railroad structure reform was carried out in earnest with the establishment of the Korea Rail Network Authority in 2004 and the conversion of the Korea Railroad Corporation in 2005(Jung and Chang 2014). The structural reform of the railway industry, which seemed to have been over for some time, was resumed with the government's announcement in 2012 to select Suseo KTX operators through the introduction of marketization tests (Lee and Kim 2014). In addition, structural reforms in the railway industry have been carried out, with the Korea Railroad Corporation acting as a holding company and a passenger transport business centred on the main rail line like the German-style holding company model, and the railroad industry restructuring reform being promoted to convert to a subsidiary system such as railway logistics companies, railway vehicle management companies, railway facility companies, and subsidiary companies, and the current control rights carried out by the Korea Railroad Corporation to the Korea Railroad Corporation (MOLIT 2013) in the name of the purpose of strengthening the public nature of the control (Lee 2017).

In addition, laws and plans related to railway development have been made and implemented. In 2006, the First Basic Plan for Railway Industry Development (2006-2010) was formulated and announced. In the first basic plan, it was evaluated that there was no comprehensive target consciousness for improving the competitiveness of railway traffic as it was planned under the vision of "realizing fast, safe and convenient railways" without presenting a goal for the transport sharing rate as it was planned as a concept of establishing plans for the implementation of various areas such as infrastructure, safety and operation, including the mid-to-long-term national rail network construction plan, comprehensive plan for railway safety and management improvement. In the first basic plan, a total of 32 major tasks were presented in seven key areas: investment and maintenance of railway facilities, improvement of railway management and services, strengthening railway safety, establishing railway connection water transmission systems and streamlining railway logistics, fostering the railway industry and developing technology, training and supply management of railway personnel, strengthening the international cooperation system for railways, and entering overseas markets, but the results of the plan were not satisfactory. Most of all, the railway transportation volume did not increase except for metropolitan railways due to the lack of investment in railway facilities, low-speed competitiveness, and insufficient connection transportation system, and thus the railway transportation sharing rate remained stagnant. (Yang 2012).

Amid this overall understanding of railway competitiveness factors, the government established the Second Basic Plan for Railway Industry Development (2011-2015) in 2011 under Article 5 of the Framework Act on the Development of Railways under its policy goal of becoming a world-class railway nation (MOLIT 2011). With the goal of increasing transport sharing rate, reducing railway accidents, increasing railway technology, and expanding overseas expansion, it is an indication of its determination to realise low carbon, green transportation. Major strategies proposed to achieve these goals include establishing a national railway network centred on KTX high-speed railways, strengthening railway-oriented transportation systems such as providing customer-oriented transportation services, and developing a complex transit centre, strengthening the competitiveness of green railway logistics by expanding logistics infrastructure, creating a competitive environment for improving the management of railway services and operating institutions, enhancing the efficiency of railway construction through inefficiency and waste removal, and strengthening competitiveness through diversification of profit projects such as station areas (MOLIT 2011, Yang 2012). This second basic plan for railway industry development was carried out 76% and achieved in many ways, but it was also confirmed that it should be supplemented. Among the things that need to be supplemented is the need for mid-to-long-term railway operation strategies, the lack of private capital, the need for expansion of high-speed railways, and the limited construction of railway networks in metropolitan areas, which were later included in the third basic plan for railway industry development (MOLIT 2016).

Later, the government established the National Railroad Network Construction Plan, which aims to carry out railroad investment efficiently and systematically. The main contents of the plan were mid-to-long-term railway construction plans, resource procurement plans, and environmentally friendly railway construction plans, and the first National Rail Network Construction Plan (2006-2015) aimed at improving speed competitiveness, improving accessibility, improving stability, eco-friendliness and comfort under the motto "Railway that realizes people's happiness and regional development." As tasks for this purpose, the government planned to expand high-speed railway networks nationwide, expand facilities in sections that were difficult to transport, form high-speed railway logistics networks, and establish a railway-centred transportation system.

The second National Rail Network Construction Plan (2011-2020) calls for consolidating the national territory through a railway network and reorganising it into an open structure. With the goal of integrating major cities nationwide into one urban area by connecting them into one and a half hours of daily commutes, the focus has been on connecting major hubs with high-speed KTX networks, establishing a 30-minute wide-area express railway network and a green railway logistics system in metropolitan areas, and creating a convenient railway environment (MOLIT 2011). According to the 3rd National Rail Network Construction Plan Report (MOLIT 2016), the 1st and 2nd plans have resulted in the expansion of new routes, the improvement of existing routes and the improvement of over 300 km of subway lines. In addition, the high-speed railway was installed to shorten the travel time of Gyeongju and Honam axis to two hours, and the double track and subway system of general railways increased the speed of transportation and improved the service, and the establishment of a new wide-area railway line resulted in the improvement of the transportation system. As a result, demand, which had continued to decline, has been on the rise since 2004. However, various problems also emerged. When fertilised with other OECD countries, railway facilities remained scarce, and polarization of facilities emerged. The combination of state-of-the-art high-speed railways and existing railways resulted in differences in facility level and service. This lack of consistency has led to inefficiency in train operation. Thus, the third National Rail Network Construction Plan (2016-2025) was formulated, including measures to guard against problems revealed in the implementation of the first and second plans.

The 3rd National Rail Network Construction Plan is a mid-to-long-term plan for carrying out railway investment efficiently and systematically. The main contents of the plan for mid-and long-term railway construction, the procurement of required resources, and the search for environmentally-friendly railway construction were aimed at leading efficient, competitive railways, regional development, and establishing a safe and convenient railway network. To this end, the main tasks are to eliminate the bottlenecks in the intensive railway operation section, connect sections that have been cut off from train operation, connect major cities across the country in two hours, shorten commuter hours in metropolitan areas, create convenient facilities for safe use, activate railway logistics for strengthening industrial competitiveness, and prepare for the establishment of an integrated railway network on the Korean Peninsula in preparation for the unification era (MOLIT 2016).

4.2 The technology innovation of the railway industry

Industry innovation is an activity which related to a lot of uncertainty. Based on a study of Korea’s automotive and semiconductor industry, Kim (1997) found that the Korean firms' technology approaches tended to include the following four stages: preparation, obtaining technology by transfer, strengthening the study and absorption of the technology within the enterprise, and improving the technology. Also, he determined that, in establishing developing enterprises' technical capacity, there are three types of typical stages, such as exemplary imitation, creative imitation, and innovation. (In the after studies, Zhao explained that the developing country’s technical learning went through the following four stages: import of technology, imitation, creative imitation, and naturalised innovation).

Technical regimes consist of technical opportunities, the justification of innovation, and the cumulative and knowledge-based nature of technological progress. Lee and Lim (2001) presented three patterns of catch-up from the experience of Korea: path-following, stage-skipping, and path-creating. Path-following means companies in developing countries will follow a more effective way of how innovations companies have done before. Stage-skipping allows developing countries to skip certain stages and proceed with the next step alongside innovative companies in developed countries. With path-creating, an innovative company can develop its technology to bridge the gap between industry leaders and the way it was operating previously. Here, both stage-skipping and path-creating are step-by-step approaches.

Railway advanced countries such as Europe, the U.S., and Japan are seeking to enhance their status as advanced railway countries by studying leading technologies centred on large-scale research and development. The biggest reason is that the infrastructure industries such as nuclear power plants, aviation, and railways are not simple manufacturing and short-term use products, and therefore the maintenance of operation is important for system industries for at least 30 to 80 years upon initial introduction, so they need a value plate of more than efficiency for public purchase of such industrial products, and the economic effect generated by protecting the railway and parts industries is very great (KOTRA 2014). Therefore, the majority of countries do not open their railway and parts industries to foreign markets in terms of industrial protection. In other words, developed countries are developing the international competitiveness of vehicle manufacturers as well as parts makers based on their exclusive domestic market through their railway and component industry protection policies (KIP 2015). The details of technical development support for the development of industries in major countries are shown in Table 14.

Table 14 Major details of technical development support (KOTRA 2014)

Country	Major Policy Contents	Note
Germany	The Ministry of Economy and Technology supports railway technology development in terms of 'high-tech strategies' and 'innovation support programs for small and medium-sized enterprises (Korea-Germany International Joint R&D Program in conjunction with Zentrale Innovations programme Mitelstand (ZIM) in Germany).'	•The goal of the high-tech strategy - strengthening Germany's global position in high-tech industries - efficient commercialization of knowledge through government-industry links - providing a successful foundation and sufficient financial support •ZIM aims to help small and medium-sized enterprises innovate, grow and strengthen their competitiveness, and create future-oriented employment.
France	•Strengthening strategy committee for the railway industry: The government, local governments, and businesses jointly participate in making practical decisions on policies (Minister 3, Representative of Local Autonomous Entities, Joint Representative of Korea Railroad Industry Development strategy committee of the railway industry: • Support category: 1) Direct support for public procurement of the railway	• Launched in 2013 to foster the railway industry as a strategic area •In the next 10 years of public procurement, between 50 and 6 billion euros in research funding, 40 million euros in 2013 and 40 per cent in tax support will be reduced in corporate taxes, while employment will be provided under the employment agreement system to foster research projects and Ph.D.-level human resources and support employment.

	industry; 2) financial support for research and development; 3) tax support for research and development; 4) employment support	
USA	•The Federal Railroad Administration's policy is to enhance railway safety, optimised railway network-rock maintenance, environmental protection officers •There are R&D departments within the Federal Railroad, where R&D priorities, support selection, and input budget are determined (one-fourth of railway R&D funds for railway vehicles and parts).	R&D in the six areas of propulsion is track, vehicle and part, control and communication, human error, railway system, and in vehicles and parts, it is part life extension by preventing line and collision, detecting and controlling technologies for vehicles and components, early detection of defects and development of new materials.
Japan	Providing half of the necessary expenses and intellectual property rights to corporations that possess technology development capabilities for 16 new technology, safety and environment-related themes	The theme of 2012: Improving the seismic resistance of tramway columns and historical ceilings, developing platform doors for each vehicle door location, and accumulating batteries for railways (energy saving)

In particular, in Europe, although the EU does not explicitly have laws and guidelines for protecting industries, it has limited opportunities for non-European countries to participate in railway and parts industries by applying strict technology and environmental regulations, while limiting their participation in other regions' bids, including European standard standards, supply performance, facilities and quality levels (KIP 2015).

In the case of Korea, most of the railway technology policies come from the national industrial technology policy. Governments play a role in enforcing policy at the Landscape-level in MLP. More granular policies are passed to government agencies under the government to apply to actors in designated regimes and niches levels. It would be more accurate to note that the policy outcomes here are handled at a regimes-level. Furthermore, niches-level is affected by those policy outcomes. When it comes to KTL, it can be considered as an actor close to regimes-level and related to landscape level as well because KTL is a kind of government agency, however, its participating in technology development is closely related to niches-level. Therefore, this agency can seem to be located between three levels (Multi-level actor).

Various national policies have made the development of railway industry technology. In the past, the railway technology policy focused only on infrastructure maintenance and railway operation in the era of Japanese imperialism. For this reason, there were no mid and long-term plans for railway technology development. The technology policy which to solve the pending issues showed the lack of a long-term plan. Also, the railway technology was ignored, therefore, the technical development effort was insufficient. Moreover, there was a large gap between overseas technology, and only partial implementation of existing system operation policies (Cho, Jeong et al. 2017). In the 1980s, a new perspective emerged. Since 1980, it was the period of revival and resurgence of the Korean railway. Until the late 1970s, it took an important role in people's transport and for the industry. However, there were a lot of problems, such as disconnection, slow speed, insufficient timelines, poor quality of carriages and locomotives (KORAIL 1995). The development of highways brought the spread of high-speed buses and automobiles and became a threat to the railway. So, as the 1980s began, improvement took place gradually. Korean government and companies have begun to invest in the underdeveloped railway. They started to fix the track that was single to double, improve bad track and the problem of regularity and frequent delays from 40% in 1979 to 90% in 2003 (MOLIT 2013).

Due to road congestion problems, which began in the 1980s, the need for public transport expansion has demanded the expansion of urban railways as well as general railways. Since 2004, the railway has peaked due to the opening of the high-speed railway and the expansion of the metropolitan and urban railway. The railroad, which had been declining for a while by road traffic, developed again in the late 2000s. Until then, the government's transportation policy was thoroughly road-based. However, due to limitations in road traffic and the problem of environmental pollution caused by overflowing automobiles, the benefits of the railroad's mass transportability, timelines, and environmental friendliness have been highlighted. In response, the government has established a mid-to-long-term railway policy by establishing a national railway network plan and supporting railway improvement and new railway lines, while providing more support for railway technology development so that it can break its lead in the competition with advanced countries.

As demands for safety and comfortable service of transportation have increased, the railway industry has also encountered a need for higher levels of technology systems. First, according to lifestyle change, a convenient and comfortable railway service is required. Advanced technology is also required for the development of high-speed railway technology and the speed improvement of the existing system. Moreover, intelligence technologies of vehicles such as vehicle control, communication, and fault diagnosis as well as train operation and intelligence technology of railway facilities became necessary. Furthermore, increasing demands for stability enhancement have required technologies to secure railway safety technology and various systems' reliability. As the economy becomes more important due to economic income improvement, energy efficiency and noise vibration and environment-related technology have become important. Above all, as intercity railway connections are needed, there is also a need for technologies to standardise vehicle, electricity, signal, line and structure management and planning areas.

Korea's most important national plan for railway technology development is the National Transportation Technology Development Plan. This was implemented in 2004 and was a five-year statutory plan to integrate and systematise government transport aircraft alcohol-related policies to promote R&D in transportation technology. The goals include improving the localisation rate through the development of core railway devices, thereby reducing railway transport time and increasing transportation capacity, and supporting standardisation technology research and development. The following Table 15 shows a summary of its casting technology development tasks.

Table 15 Major Technical Development Tasks in the Railway Sector of the National Transportation Technology Development Plan (MOLIT 2002)

Fields	Technologies	Tasks
High-speed railway	Reliability and Safety	▪Development of operation efficiency and stabilization technology for the high-speed railway system ▪Development of passenger and freight complex transportation system ▪Establishment of performance standards, safety standards, and diagnosis standard system ▪Establishment of the development system for practical use of the vehicle system
	Stabilisation of system	▪ Securing Practical Use of Vehicle Systems ▪Securing Train Control System Stabilisation Technology ▪Improving the Safety of Track Structures and Securing Practical Use Technologies ▪Securing Korean Multi-Promotion System Technology
Railway Technology	Development of Practical Technology for High Speed of Existing Lines	▪Technical integration and linkage of vehicles, tracks, electricity, and signal systems ▪Development of train performance test standards and evaluation technologies ▪Development of operational technologies based on railway linkage ▪Basic and detailed design of electric tilting vehicles of class 180km/h

		▪Developing interface technologies between vehicle components ▪180km/h electric tilting vehicle prototype vehicle production. ▪Evaluation of existing track speed.
	Development of Railway Maintenance System Technology	▪Development of technologies for track and civil structure maintenance and safety improvement ▪Development of technologies for maintenance of electric and signal facilities and safety improvement ▪Development of technologies for improving the performance of vehicle components and improving the environment
Urban Railway Standardization	Standardisation of Signalling Systems	▪A Study on the Standard Specification of Signalling System ▪A Study on the Improvement of Existing Urban Railway Signal System ▪Development of Key Devices for Demonstration Building
	Standardisation of Power Systems	▪A Study on the Standard Design Criteria and Construction Guidelines for the Standardised Power Supply System ▪Development of Localisation Technology for Core Devices in the Power Sector
	Standardisation of Track Systems	▪Standard design standards and construction guidelines for track systems ▪Standardization of environment and safety facilities ▪Development of prefabricated slab rails for urban railway factories
	Standardisation and Informatisation of Maintenance System	▪ A Study on Standardisation of Maintenance System ▪Development of Urban Railway Maintenance Information System
	A Study on the Standardisation System	▪Research and development of standards for standardisation ▪Sharing and distributing urban railway technologies ▪Studying the standardisation system for urban railroads
Lightweight Electric Railway System	System Engineering	▪Construction of Korean lightweight electronic items suitable for the domestic environment with safety, economic feasibility, and future-oriented design
	Vehicle System	Development of 3 vehicle systems of rubber/steel/LIM AGT

	Power Supply System	Development of the 3rd Orbital Power Supply System
	Signal Control System	▪Development of Unmanned/Wireless Communication Signal Control System
	Track Structure	Development of train Orbit and Structure

The Korean government has also established the Framework Plan for Railway Technology and Heavy Equipment (Lee 2006). The main strategies are to promote the innovative development of railway technology through selection and concentration, establish advanced infrastructure to strengthen the competitiveness of railway technology, strengthen railway technology's ability to respond to changes in the internal and external environment, establish a cooperative system for the advancement of railway technology and expand support, and analyse the current status of research and development of railway technology. What is important in these development plans is the advancement and localisation of railway technology. As a strategy, the government sought to promote the advancement of railway technology through selection and concentration by promoting the localisation of core element technologies to achieve self-reliance of railway technology, continuously developing the Korean railway system with global competitiveness, and actively utilising the already developed technology to increase the efficiency of investment in research and development. It aims to establish a foundation for strengthening railway technology's competitiveness by fostering excellent science and technology personnel to lead the innovation of railway technology and securing international-level research facilities and equipment necessary for the development of railway technology. It also aims to continuously create railway demand by strengthening safety, speed and comfort, develop technologies considering national tasks such as environmental conservation and exchange between South and North Korea, and strengthen railway technology capabilities against environmental changes by promoting contact with future technologies such as information, new materials and alternative energy. Also, the company had a strategy to expand the cooperative system and support of railway technology by establishing a cooperative system with related agencies for effective technological innovation and by expanding investment in railway technology and organizing support projects (KRIHS 2008). Due to these efforts, Korea Railroad Technology has seen in many respects the result of improving its competitiveness in major research areas of railway technology as in Table 16 (KRRI 2018).

Table 16 Global Competitiveness by Research Field (KRRI 2018)

Major research field	Detailed research field	Highest Technology Holdings	Relative Technical Level (%)

Vehicle/Mechanical Technology	Vehicle system	Germany/France	83
	Body and equipment	Germany	84
	Driving/braking/propulsion control	Germany	80
	Magnetic Levitation	Japan	82
Orbital/ Civil Engineering Technology	Orbital/Runway Technology	Germany	86
	Railway bridge Technology	Germany	86
	DB Systemtechnik/rail tunnel Technology	Germany	85
	Station Building Technology	Japan	88
Electrical/signalling technology	Rapid Electric System Technology/Power Conversion and Supply	Germany	88
	Tramway Technology	Germany	94
	Signal Control Technology	Germany	80
	Communication Transportation and Network Technology	Germany/France	86
Transportation/logistics/environment/safety technology	Railway Traffic Planning Technology	Germany	82
	Railway Proficiency Technique	Germany	79
	Railway Logistics Technology	Germany	78
	Risk diagram Technology	France	80
	Accident prevention/response Technology	Japan	80
	Comfort/Convenience Technology	Germany	82

The government has been trying to establish and support the railway industry’s environment by setting the basic plan for developing the railway industry in the first and second phases. Subsequently, After deliberation by the Railway Industry Committee based on the ‘Railway Industry Development Basic Law’, the Ministry of Land, Infrastructure and Transport (MOLIT) finalised the third plan of railway industry development plan (2016~2020), which is the highest statutory plan in the railway sector. This development plan is a five-year medium-term plan that evaluates the railway industry's status and performance in Korea. Also, it suggests directions for railway industry policies based on changes in future conditions. In this plan, mid and long-term goals and tasks for the five areas are presented. They are railway operation, railway construction, railway safety, rising the railway industry ecosystem, and restructuring the railway public castor governance (MOLIT 2006).

Amid a series of railway technology-related development and investment plans, the most recently, the Korea Railroad Vehicle and Railway Parts Development Project (KISTEP 2019) has been launched, showing that the government's support has been expanded. This is because railways are a national key transportation network and a key industry, and railways are operated by the government or state-run companies in most countries around the world to secure competitiveness in the global market, supporting the role of a national market entry barrier, such as a tricky certification system, and each building for preoccupying the market based on high technology, especially in advanced countries such as Europe and Japan. Above all, the new vehicle and parts and vehicle maintenance market account for more than 60 per cent of the total railway vehicle market according to the research in 2018 (KISTEP 2019). However, weakening the competitiveness of domestic parts manufacturers, reducing investment in them, and high dependence on imports of components greatly impact them. Accordingly, a support plan (2020-2025) is being implemented to foster the railway parts industry as part of the creation of a self-sustaining industrial ecosystem by strengthening the competitiveness of small and medium-sized railway parts companies. This includes support projects for obtaining certifications to be dealt with in this study, and a plan was drawn up to support schedule management, testing and certification procedures for cooperation with railway management agencies, vehicle manufacturers, and testing and certification agencies, which are related to railway certification.

4.3 Chapter Summary

In this chapter, the entire railway industry background has been explained, such as how much the railway industry has become a national infrastructure industry and what role it has played. To sum up, the national railway system can be regarded as a business involving multiple products and services. The railway industry is essential because it can solve various traffic problems in an environmentally friendly way, and it can contribute to the national economy with low energy consumption. It is also an efficient means of transportation that can contribute to various environmental policies and the role of public transportation and the driving force behind economic development as a core industry.

Globally, railways are one of the most energy-efficient transportation for cargo and passengers, showing steady growth, which has been 3.6% annually since 2017 (IEA 2019). The railroad industry is an industrial sector that requires huge investments in construction, signal communication, steel, vehicles, etc., related to railway construction because of its strong social overhead capital (Nash and Preston 1992). The railway industry is an industry that encompasses systems that systematize tracks, roadbeds, stations, vehicles, etc. and includes all research and development, manufacturing, and sales related to railways (Kaewunruen and Remennikov 2007). In particular, it has high barriers to entry into production or technology, because only companies that can afford to finance large orders, provide project financing, and build turnkey infrastructure can expand their presence in this field (Iacono, Martinez et al. 2012).

The world's railway supply market is centred around Europe, with sustainable demand expected to continue in mature markets, with railway control and infrastructure expected to grow at the highest rate (Schwilling 2020). It is because improving products and services is a critical factor in market success, and the purpose of this study in terms of developing railway parts technology and performance testing provides examples of research towards success in the railway parts market.

For the railway industry to perform its role well, there are structures in place that consist of cooperation between various sectors. These railway structures are introduced using the British and Korean cases. Furthermore, various countries' efforts to develop technology for innovation in the railway sector are explained, including various policies that have been put in place by the Korean government. Lastly, the Korean railroad component development support plan is introduced as the background of the railway technology certification industry and market, which is the specific focus of this research which is presented in Chapter 5. Subsequently, Chapter 5 will provide a more detailed description of this, along with the case studies.

5. Study of the Institutions related to Technology Accreditation

Preparations for the overseas advancement of the railway industry should be carried out under the national level of preparation and systematic implementation strategy from a middle and long-term perspective. In the case of Korea, a survey on the most important railway-related factors when the railway system enters the overseas market shows that the leading company's acquisition of international certification related to technology quality accounted for 28.6% of the total in the factors, including financing, price and payment conditions, vehicle and parts technologies, and the importance of technology certification in overseas expansion. In addition, a survey of the most important general factors when the railway system enters the overseas market shows that government support and international level strategic partnership are important factors (Oh, Kim et al. 2007, Moon. J. and Kim. D. 2011). These surveys confirm that government support and the development and management of networks have much to do with the certification industry in order to expand and develop the technology certification market.

In this chapter, case studies are conducted on overseas technology testing supported by KTL, along with an investigation into the structure and systems of the European and Korean technology certification industries. Through this, we will be able to observe how the KTL formed and used the international network with the support of the Korean government, and how it influenced the process of overseas technical certification tests.

5.1 Overview of the accreditation process in the EU

The European certification system can be divided into largely government-led or private-led systems. The government-led certification system includes TSI and EN, which are the keys to ensure interoperability on different railway lines in Europe under the EU's policy guidelines. Accordingly, the EU enacted and applied the EU standard which is a pan-European integrated standard, to define the TSI as a form of the statute and to determine the suitability of individual goods or systems to the TSI. While the TSI is a mandatory regulation, EN is recognised and applied as an international standard, with the recommended standards, but the size of the pan-European railway construction site accounting for a significant portion of the world's railway market. (KAIA 2010).

The private-led certification system includes the International Railway Industry Standard (IRIS) as a quality certification system for railway products organised by the Union des Industries Ferroviaires Européennes (UNIFE). The IRIS certification system is an international standard specialised for the management of quality management systems for suppliers of major railway vehicle makers around the world, and the IRIS certification is essential for delivery to railway vehicle companies (UNIFE 2020).

Established under the leadership of Siemens, Alstom, Bombardier and major parts makers, it has developed into industry-specific standards similar to those being applied to the automobile, aviation and food industries (Park 2014). IRIS includes railway specialisations based on existing ISO 9001 (UNIFE 2020). ISO 9001 is an international standard based on the eight principles of quality management such as being customer-oriented, process-approach, continuous improvement, for evaluating organisational ability to meet requirements. ISO 9001 is applicable to all activities related to the quality of the product, i.e. all phases within the life cycle of the product and process, and is applied in many industries and services (Kim, Park et al. 2014). Meeting all the requirements of IRIS means that the entity complies with the highest level of standards required by the railway industry, which greatly helps to improve the competitiveness of the entity. In addition, if it is certified and registered in IRIS's database, numerous railway-related agencies and companies will be able to verify the information, which means that they can firmly establish their position as suppliers of the technology products (UNIFE 2020). IRIS is supported by UNIFE and has five detailed organisations under its wing, culminating in a Steering Committee of major vehicle manufacturers and parts manufacturers. The Steering Committee is responsible for the development and implementation of IRIS systems, the formation and monitoring of IRIS Management Centre organisations, approval against certification bodies, approval of membership and withdrawal, cooperation with other associations and agencies, and appointment or designation of IRIS working groups (UNIFE 2020). The organisation's structure is as shown in Figure 13.

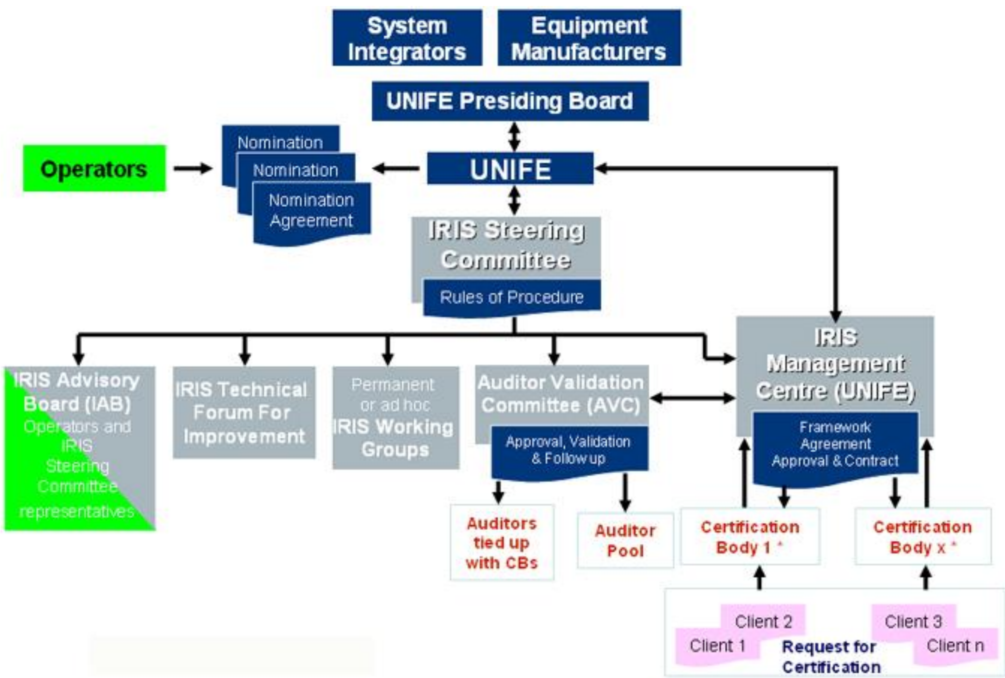

Figure 13 IRIS Governing Structure (UNIFE 2020)

The main purpose of IRIS is to enhance transnational competitiveness by enabling railway products produced by railway-related enterprises to meet globally recognised quality levels. In addition, the purpose of the project is to improve the quality of the railway industry supply chain through the development and implementation of a general-purpose system for the evaluation of business management systems (BMS) which is specialised in the railway industry based on ISO 9001 that is a service quality management system-oriented assessment such as quality of products and management system. For this purpose, the IRIS certification process consists of three stages as in Figure 14, in which the company requesting the technical test is able to plan the optimal method for the technical test by examining whether the related matters have been prepared and implemented as a preliminary examination to determine whether the company is qualified for the certification. The second stage is a practical testing stage, where the technology is tested based on all the requirements required for IRIS certification. At the same time, a test review is also made to provide mutual inspection certification to all railway industry suppliers with the same guidance. The third stage is the certification phase, which, upon successful completion of the test, issues a certificate from IRIS, which is valid for three years, is published on the IRIS' website and is reviewed annually in accordance with IRIS' requirements. (UNIFE 2020).

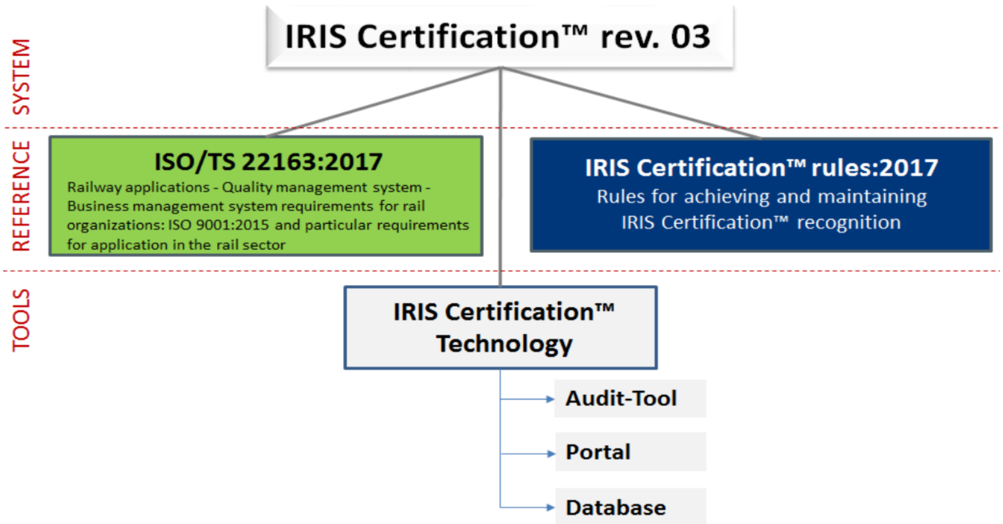

Figure 14 IRIS Certification™ system rev.03 (UNIFE 2020)

5.1.1 Accreditation process in France: Eurailtest and SNCF-AEF

Eurailtest is the world's leading railway testing agency, closely linked to several internationally known certification bodies. With more than 80 years of history, it is a testing and certification body of more than 400 experts, established by the French National Railway Company (SNCF) and Autonomous Parisian Transportation Administration (RATP), and works with seven world-class railway research institutes owned by the SNCF and RATP. To meet the aims in customer satisfaction, technical excellence, professionalism, impedance and impartiality, it tests railway facilities and technical designs of various types of railway systems and subsystems to help them lead to actual success, to ensure safety by solving legal and technical problems, and to find and solve technical problems affecting railway operation and maintenance. The know-how, which can be gained from engineers in experienced laboratories working with Eurailtest, is considered as a great advantage of Eurailtest.

In addition, Eurailtest is trying to meet the needs of its customers by using its own network of experts to combine complementary technologies to provide the most appropriate solutions, as well as testing railway technology, and by using a large scale of expert networks to provide other complementary services. For customer satisfaction, the company uses the expertise of vehicle and facility experts from the SNCF Group and the RATP Group, and also utilises a network of recognised experts in related fields such as forensic experts, professional lawyers, insurance companies, etc. The availability of all these diverse resources is one of the great advantages of Eurailtest, and external certifications obtained by Eurailtest member laboratories allow clients to use the test service results with confidence. This is partly because Eurailtest has a process to ensure the highest possible level of service in a more complex railway environment by obtaining the ISO 9001:2015 certification in recognition of its verification, control, analysis and certification capabilities.

First of all, operating railway vehicles in France or Europe requires proof of compliance with standards. To this end, Eurailtest identifies the complex and limited regulatory environment for certification, regulates the approval processes, and performs the required tests, which are largely divided into sections of rolling stock, infrastructure, and railway arrangements. At first, the accreditation process of railway technology is very complicated. The intervention of experts is a necessity for testing and execution of the accreditation process, therefore, Eurailtest supports clients by helping clients identify tests as a part of the process, and assisting the drafting of the characteristics of the equipment and the parts to be tested according to the reference, if necessary. Also, Eurailtest supports clients to take the circulation authorisation, and publishes the testing result which comes from its testing labs. Secondly, in terms of infrastructures, by using high-quality test equipment, such as high-speed trains, track geometry measuring vehicles, and load trains, Eurailtest makes an effort to meet the demanding needs of customers. Experts in Eurailtest increase work and test speed in the final stage of the test process and enable characterisation such as vehicle/lane interaction (behaviour tests dynamic) and pantographic/catenary interaction (capture tests). Thirdly, Eurailtest' s laboratories use specialized knowledge of railways and urban environments to provide risk management, health, and safety services. In addition, to qualify for railway equipment, Eurailtest provides several international services with measurement, testing and expert opinion, including confirmation of compliance with test specifications, support for the preparation of documents for national and certification bodies, support evaluation of comfort, safety and reliability based on test results, analyse accidents, identify causes of failure, and provide improvement and correction due to damage.

The test of the Eurailtest is related to measurement and investigation. To ensure safety, it is essential to measure and investigate performance, comfort and the possibility of equipment or railway facilities. For this purpose, the test is divided into parts such as Electric, Physicochemistry, Acoustic, Environment, Health and Safety. First, in the field of Electric, testing and measurement are essential to test the mechanical properties of products or equipment at the design or qualification stage of railway infrastructure and railway vehicle inventory equipment. With tests in the field of Electric carried out in the test bench, railway mechanics engineers in the test lab can intervene in the event of failure or early wear to suggest corrective and complementary methods, and evaluate the equipment to determine the cause of the failure or wear. With regard to the physicochemistry test, analyse and evaluate the physical properties of a product or material. These tests involve verifying the physical properties as well as the compatibility with other elements. Acoustic testing, which occupies an important position in railways, is a test to reduce the impact of noise disturbances, and the sound engineer in the lab provides the customer with a complete check of acoustic and vibration. The Environment, Health and Safety test is an area that is getting more and more attention, and depending on what the problem is, Eurailtest is making efforts to propose various measures in these three areas. Seven testing laboratories at Eurailtest have conducted tests to ensure the highest levels of stability and reliability in various such areas for more than 70 years. The laboratories connected to them can be arranged as shown in Table 17.

Table 17 The characteristics of test laboratories of Eurailtest (Eurailtest 2020)

Test centres	Main characteristics	Strong points
Railway Testing Agency (SNCF - AEF)	Carry out testing in a variety of areas: mechanics, electrics, industrial hygiene, and the environment.	• Rolling stock type approval and commissioning. • Access to infrastructure • Expert appraisals • Chemical hazards • Training
Laboratory Tests and Measurements (RATP - LEM)	Perform acceptance tests for the RATP procurement department in areas relating to infrastructure, rolling stock, equipment, buildings, staff and users	• The mechanical section, which handles railway safety-related tests • The electrical section, which is responsible for measurements relating

		to the railway environment and rolling stock • The Physicochemical section, which is in charge of fire behaviour tests
Department of Measurement & Testing (SNCF - DGII ME)	Provides Measurement and Testing Services for the railway infrastructure in the fields of Signaling, Telecoms and Electrical Engineering.	• Electromagnetic Compatibility (EMC) • Electrification (SYE) • Signaling Systems (SYS) • Signaling Equipment (MAS) • Mobile Means of Testing (MME) • Transverse Edge-Ground (TBS) • Metrology (METRO) • Online Testing Organisation (OEL)
The Electrical Energy Transformation and Distribution Unit (TDE) of RATP's Infrastructure Management Department (GDI) (RATP - GDI TDE)	• Operation and preventive and corrective maintenance of the entire high voltage network (PHT - Cables - PR - PEF), • Preventive and corrective maintenance of the low voltage traction distribution network RER and Tramway (Catenary or Airline Contact) and Metro (Supply 750V Traction rail), • Preventive and corrective maintenance of the lighting and the low voltage of the inter-stations, stations Force Lighting, the workshops of the RER and Tramway, Tramway stations, • The heritage maintenance of PHT, Cables, PEF and LAC, Note: The heritage	• The unit also has the mission to provide engineering services to customers internal or external to the company for equipment in its area of expertise • The objective of TDE is to ensure the availability of electrical energy in complete safety, meeting the economic, social and environmental requirements.

	maintenance of PR, other traction equipment, and low voltage is provided by the ING Engineering Department under TDE project management. • Logging manoeuvres for maintainers, engineering or outside contractors who request them • The measurement of earth wells of the entire RATP.	• Maintenance of Low Voltage Catenary (MCBT) • Operation and Maintenance of the High Voltage Network (EMHT)
Centre of Expertise Rail (SNCF - CER)	Product qualification tests: • Approval of fixed or mobile spark welding machines according to NF EN 14587-1, NF EN 14587-2; • Homologation of fixed welders for core antennas according to NF EN 14587-3; • Approval of aluminothermic welding processes according to EN 14730-1; • Approval of welding consumables according to NF EN 15594. • Homologation of track material (fishplates, cutting discs, etc.) according to the current standards. Expertise: • Failure analyses of rails, cores, welds. • Track equipment failure analysis: joints, splices, switchgear, bolts, etc. • Expertise on-site and on track. R&D missions: • Monitoring the development of prototypes. • Assistance in the development of CND inspection methods.	• Specialist in the rail field. Possibility of analysis on-site. • Specialises in expertise and testing related to rail products and infrastructure equipment. • Strong responsiveness.
RATP - ING / STF	• The ING Department is contributing to the modernisation and strong involvement of RATP in the extension of urban transport as well as to the Group's valuation of niche expertise with high added value in the world.	The ING Department is made up of a technical unit bringing together a thousand engineers and integrating four Business Units:

	• Within the engineering department (ING), the Railway Transport Systems Unit (STF) is involved in the field of railway systems (on Metro, RER and Tramway modes), for signaling, automation, command and control of trains, passenger interchange systems and traffic control systems. Within it, the QS entity is in charge of Systems Qualification with AQM (Material Qualification Workshop) and AQL (Software Qualification Workshop)	• ISE (Electrical Installations and Systems), • ILO (Transport Structures and Infrastructures), • STF (Rail Transport Systems), • SVM (Traveler Systems and Mobility);
Track Test Centre (SNCF-CEV)	• Specialise in tests relating to the components of the track (sleepers, fasteners, underfloor soles & mat under ballast). • Concrete cross tests according to EN 13230 • Plastic test rails according to European standard project • Test fastening systems according to EN 13481 & EN 13146 • Underbody flange tests (USP) according to EN16730 • Under-ballast carpet testing (UBM) according to European standard project • Fatigue tests of rail welds according to EN 14587 • The expertise of the failures of the components of the ballasted track and the track without ballast	• Specialist components of the track • Active participation in standardisation groups (NF, CEN, ISO & UIC) • Strong responsiveness

Among them, the Railway Testing Agency (SNCF–AEF) is a cooperative testing laboratory for Eurailtest and conducts tests in various fields, including machinery, electricity, industrial hygiene, and environment, which conducted the 2018 technical certification test among the case studies in this paper.

5.1.2 Accreditation process in Germany: DB (Deutsche Bahn) Systemtechnik

DB Systemtechnik is the Deutsche Bahn Technical Center, a Designated Body (DeBo) that verifies compliance with national requirements and issues necessary certificates of conformity within the certification process, and DB Systemtechnik is an organisation that evaluates compliance with requirements in Europe as defined in TSI. It is also a partner of the UK-based certification authority and a relevant partner of Notified Body (NoBo) EISENBAN-CERT (EBC). In addition, as an Assessment Body (AsBo), it conducts an independent safety assessment of the risk management process for safety-related and significant changes (AG 2016).

First of all, DB Systemtechnik provides a wide range of engineering services for the railway engineering industry, with years of experience and unparalleled system know-how, making it a leading competency centre for the railway engineering industry. System knowledge and practical experience are essential in order to fully understand the complex railway system and provide the necessary support to the railway sector. In these regards, DB Systemtechnik has extensive technical expertise, has the necessary experience in terms of operation and maintenance, and has an operating system that helps reduce costs and improve quality through continuous management (DB 2013). DB Systemtechnik performs all kinds of tests on vehicles, parts and infrastructure in the business sector of approval management, testing and certification, and has adequate test equipment and measurement vehicles that can be used to meet all possible needs, which contribute to the safe, reliable and efficient railway operation by providing enterprises across the railway sector with customised testing and solutions that comply with exactly the appropriate standards and requirements, and services that meet the highest quality standards.

DB Systemtechnik test centres and expert organisations are registered with the German Federal Railroad as relevant partners for the Eisenbahn Cert (EBC), an interoperability notification agency, and a total of 19 laboratories are operated in Germany and France, authorised by DIN EN ISO/IEC 17025:2000 (DB 2020). DB Systemtechnik supports all certification tests for obtaining licenses for vehicles in service, providing an efficient, reliable and customised approval procedure that complies with national and European requirements. Designated test stands and testing laboratories, designated assessors and experts on all approval-related topics, and designated railway transport companies dealing with all activities related to technical testing and test runs are proving the various resources and capabilities DB Systemtechnik has for the approval process. Table 18 outlines what field of railway technology is being tested at 20 testing laboratories at DB Systemtechnik (AG 2018).

Table 18 Testing Laboratories and Fields of DB Systemtechnik (AG 2018)

Laboratories	Testing field
Acoustics and Vibration Testing laboratory	Outside noise, vibrations, speech intelligibility, etc.
Aerodynamics test laboratory	Driving resistance, loads on noise barriers, movable objects on the track, etc.

Air conditioning test laboratory	Heating, ventilation, pressure protection equipment, test runs, etc.
Battery technology test laboratory	Battery and charging systems, durability, malfunction investigations and certification testing
Braking systems test laboratory	Brake discs, brake pads, wheel slide protection, etc.
Running characteristics test laboratory	Vehicle reaction and contact geometry, vehicle dynamics testing
Electromagnetic compatibility (EMC) test laboratory	Compatibility of vehicles with track circuits, influence on signalling equipment, etc.
Electromagnetic fields (EMF) test laboratory	Electromagnetic fields, field distribution, etc.
Fatigue strength test laboratory	Force, distance, strain, material tension, acceleration, temperature, pressure
Fire safety assessment test laboratory	Combustibility, smoke density, smoke toxicity, etc.
Fuels test laboratory	Quality assurance, condition analysis
Testing of information technology systems	Passenger information systems, video, loudspeakers, etc.
Insulating oils test laboratory	Condition analysis: The basis for optimising maintenance costs and safeguarding reliable operation
Lubricating greases test laboratory	Approvals, quality assurance, condition assessment
Non-destructive testing test laboratory	Non-destructive testing on vehicle and superstructure components as part of maintenance
Oils test laboratory	Approvals, quality assurance, condition assessment
Pantograph/overhead line test laboratory	Contact force, dynamic response, simulations, etc.
Rail track technology test laboratory	Permanent way and rail track components, vibration testing, etc.
Spectroscopy test laboratory	Spectra library, additive quantification, early detection of abrasion and wear, analysis of impurities
Test laboratory for propulsion technology	Tonnage rating, anti-skid protection, energy consumption, diesel locomotive suitability, impedance, etc.
Test laboratory for radio transmission, transmission technology and GSM-R	Radio components, route radio supply systems, immunity, etc.
Testing - Environmental conditions	Approval, testing, durability, operating conditions, malfunction analyses, etc.

Tribological examinations test laboratory	Test stands and component tests: solutions to problems and approvals
Wheel/rail contact testing	Performance of wheels, axle shafts, rails, points, etc.

Among these laboratories, the relation to the second case study in this study, the Braking systems test laboratory conducted the technical test of the chosen company's brake pads.

5.1.3 UIC (International Union of railways)

As introduced in chapter 3, UIC was launched in 1922 after World War I, mainly by European railway operators to facilitate, streamline, and standardising railway technology. The main member is the railroad operator of each country and is the operator of the state-owned or privatised old national railways. UIC sets international standards for railway technology, promotes the operation of international trains, provides various support and technology sharing for railway operation, by developing the overall consistency of the world-class railway system, developing strategies and initiatives to improve business performance, and increasing railway transport investment, and implementing and managing projects and activities. In South Korea, the Korea Railroad Corporation, the Korea Rail Network Authority, the Korea Railroad Research Institute and the Korea Railroad University are all members.

5.1.4 The effort of the Korean government for the railway technology

It has been issued that previously, safety standards for railway vehicles do not match with advanced technical standards in foreign countries. The main reason for this is the insufficiency of technology verification. Also, they are composed mainly of performance tests. Therefore, the Korean government has reorganised various testing standards including safety standards and promote systematic development to correspond with overseas' advanced technical standards. So, the Ministry of Land, Infrastructure and Transport revised the railroad safety act in 2012 (Choe 2018). In 2017, technical standards were newly developed for the manufacturing and type approval system in order to enhance the competitiveness of the railway industry as well as to secure the safety of users (KRRI 2017). Based on Article 14 and 26 of the Act on the Development of Korean Railroad (MOLIT 2013) which is for safety and facility management, this system provides design verification of the safety, performance, major equipment of railway vehicles, testing of parts and components of main devices, testing of finished vehicles, testing of start-ups, and verification of the manufacturer's vehicle quality control system, in order to ensure safety and quality when manufacturing and importing railroad vehicles and equipment which are operated in Korea. It is also a system for certifying railway vehicles that are implemented in most countries (KRRI 2017).

The technical standards for railway vehicles were enacted based on Article 26 of the Railroad Safety act. It includes approval of types, manufacturers, and completion of railway vehicles (KRRI 2017). It aims to secure railway safety, increase competitiveness, and protect the users' interests by achieving the level of requirements for the safety, performance, and major equipment related to railway vehicles. It also includes, 1) safety requirements such as vehicle safety, performance, interface, operation and maintenance, and operating limitations, 2) design requirements for major devices such as driving equipment, braking equipment, propulsion system, auxiliary power unit, car signal system, comprehensive control and connection, 3) test standards for the type of rolling stock such as component testing, complete vehicle testing, and road testing (KRRI 2017). The railway technical standards are prepared through the deliberation process of the railroad technical review committee, which consists of railway experts and organisations interested in the railway industry, such as railroad vehicle and equipment manufacturers and railway operators.

Also, the content of the standards was prepared on an equivalent level with international standards, such as International Organisation for Standardisation (ISO), International Electro-technical Association (IEC), European Standard Specification (EN), and European Type Approval Criteria (TSI) (KRRI 2017). The primary purpose of these standards is to secure the safety of railway operations and to improve the competitiveness of manufacturers who develop railway technologies. Moreover, there have been a lot of difficulties for domestic companies to obtain overseas' certifications due to the weakness of domestic standards while the global market in this industry is leading by European standards such as TSI and EN. In this circumstance, completing the technical standards as well as the globalisation of standards for railway vehicles are also intended to bring significant benefits in terms of cost and time to Korean companies who want to enter foreign railway markets such as Europe and China (KRRI 2017).

5.2 Case-study: KTL

The Korean government is engaged in various support projects to enhance the technology of the small and medium-sized Korean railway industry and expand into the European railway market. The most important project is the development of railway parts and technology. The project includes resources to support overseas technology commercialisation. Here, we covered a case study on the test of brake pad products by the chosen company's Brakes, organized by KTL, as part of the project to support overseas certification of Korean railway technology products.

5.2.1 Introduction of the KTL (KTL 2018)

The KTL has been carrying out the overall railway testing, R&D in the railway field, Verification, Validation & Testing (VVT), certification consulting, and cooperation in external affairs. Starting with the integrated development support of the G7 high-speed railway vehicle system in 1997, KTL entered the railway market project and was in charge of the system engineering and test fence until 2002. Since 2006, the company has expanded its position in the railway market to include projects for the commercialisation of urban magnetic levitation railways, technical standards for responding to the railway type-approval system, and the development of test standards. It has supported the development of various laws and technical standards during this period. By further accelerating the growth of the railroad market, the company has been engaged in consulting to verify the suitability of railway components and obtain certification since 2014, and has participated in policy consultation with the Ministry of Land, Infrastructure and Transport (MOLIT) and planning for future railway projects. The Ministry of Land, Infrastructure and Transport is proposing strategies through the Corporate Development Policy TF, supporting the establishment of master plans and comprehensive plans for railway vehicle components, and also planning a 333 million USD high-speed railway parts technology development project (2018-2022), as well as a 176.3 billion won project to develop next-generation railway core parts (2002-2027) (KTL 2018).

The technology-related projects of KTL are divided into the following: support for the improvement of laws and regulations, conduct VVT and consulting projects for railway components, support for test evaluation and certification acquisition, the establishment of internal and external cooperation systems and promotion of institutions. First of all, MOLIT has researched the improvement of laws and systems. This is a research project that cost a total of 48.5 billion won, which aims for the development of systems for the commercialisation of urban self-compensation trains, the development of technical standards and test standards, the study of system improvement measures for the establishment of a railway integrated radio room, the technical standards for approval of railway equipment types and the technical standards for approval of railway vehicle manufacturers. In addition, a total of 46 laws, technical standards and test standards have been developed, and 30 of them have been completed by the MOLIT by the end of 2018. KTL has also supported the activation of the type approval system after the revision of the Railroad Safety Act, including the development of products that meet the standards for the type approval and verification and the securing of test infrastructure for obtaining type approval certification for small and medium enterprises related to railways (KTL 2018).

In terms of the railway component VVT and consulting projects of KTL, VVT Consulting has been commercialised and operated to establish, track, manage, and verify compliance with the requirements, considering the entire process of railway component development, divided into planning, design, production, evaluation, certification and market entry. In addition, consulting has been conducted for obtaining VVT and certification of seven railway components related to the European standard coupler system, railway vehicle parts and modules, and the high-speed cargo vehicle swing motion courtesy car system. These include emergency broadcasting and emergency lighting, braking friction systems, braking systems, accumulators and chargers, connections and air compressors (KTL 2018).

The test evaluation and certification acquisition support projects can be divided into railway component performance evaluation, railway vehicle and component type testing, VVT consulting and certification support, demand source cooperation test, and overseas institution cooperation test, and they are divided into the central performance of the test and its evaluation. First, the performance evaluation of railway parts was conducted on 21 individual (single-product) tests and 14 comprehensive (system level) tests to establish testing standards for railway parts evaluation centres and secure revisited customers through quality control. The company also saw its sales increase by 90% by bringing in an increase in the number of test cases per year (21 tests in 2016 and 36 tests in 2017). With regard to railway vehicle and component type tests, the qualification as an institution specialising in type test was secured and the reliability of test results has been enhanced by conducting driving and start-up tests for type approval of railway vehicles, and type tests for type approval of railway products and modular types. In terms of VVT consulting and certification support, the Commission successfully conducted consulting to obtain type approval of railway vehicles and components, performance certification of the Small and Medium Business Administration for railway parts, and the IRIS certification of railway parts manufacturers, and increased awareness in the railway sector. In addition, high value-added values were created through the verification of the suitability of railway components such as couplers, brake pads and compressors, and the commercialisation of various certifications has led to changes in the paradigm of supporting the information industry. Performance evaluation cooperative testing of systems and components has formed a trust relationship with demand sources, such as operating institutions and vehicle manufacturers. KTL has also achieved the expansion of the testing and certification network for obtaining overseas certifications by conducting several railway technology tests with France's SNCF-AEF, Germany's TUV SUD and DB Systemtechnik, and China's CRRC Corporation Limited (CRRC). As for the establishment of the internal and external cooperation system, with MOLIT, KTL has been contributing to establishing a policy strategy framework for fostering small and medium enterprises of railway components and a domestic and international railway test network and jointly carried out R&D and performance-sharing projects of the government. Also, various clients were secured and relationships were established, data on technical standards, test standards, certification, etc. were provided to relevant institutions, and various methods were contributed to the development of technology by holding seminars related to technology and thesis presentations in the field of railways (KTL 2018).

The analysis of various environments in the future technology-related projects of KTL can be divided as follows: 1) the legal/institutional environment of the domestic railway industry, 2) the policy environment of the domestic railroad industry, 3) the market environment of the domestic and foreign railway industry, and 4) internal capabilities. First, the Railroad Safety Act was revised in connection with the domestic railway industry. Before the revision, the government had implemented the overall railway production, operation, management, safety, and testing, and the railroad industry had been stagnant in growth due to the strengthening of technical barriers to the trade agreement. With the increase in the number of private railway operators, new operating standards were needed, and internationalisation of laws was needed to advance into overseas markets. Moreover, strengthened safety standards are needed for preventing accidents. In line with these various needs, the Railroad Safety Act was amended, and the type-approval system for railway vehicles and equipment was introduced to establish technical standards for high-speed/general/urban railway vehicles and railway supplies. Safety standards have been strengthened, and international standards have been met. However, barriers to the commercialisation of small and medium-sized enterprises were created due to strengthened safety standards, and the limitations of small and medium-sized enterprises' technical skills were found to be a problem in the process of meeting international standards. Second, regarding the diverse policy environment of the domestic railway industry, KTL has been planning and carrying out projects through the following analysis. First of all, the various responses of the KTL to the ongoing policy changes can be summarised as shown in Table 19 (KTL 2018).

Table 19 KTL's Response to Policy Changes (KTL 2018)

Policy	Contents	KTL’s response
The Moon Jae-in government's top 100 national political agenda	Strengthen the public nature of the national transportation network, strengthen the power of the land transportation industry, and establish a strong growth environment for small and medium-sized enterprises	Establishing strategies for promoting public-interest railway projects and promoting projects for fostering small and medium-sized enterprises in Korea
The Fourth National Territory Comprehensive Plan Amendment Plan	The spread of Long-term Railway Industry and Rapidisation of Base City	Promotion of projects in line with the spread of the railway industry
National Transportation Network Plan	High Speed (mainline railway, KTX) Traffic Linkage Point Activation	Proposal for development and notification of railroad laws/standards/standards
The Third National Transportation	Achieve 95% of advanced transportation technology levels	Support the establishment of a quality control system for small

Technology Development Plan	and reduce the number of accidents by 10%	and medium-sized enterprises, and support the verification of development parts suitability and certification.
The Third Basic Plan for Railway Industry Development	Strengthen the competitiveness of the parts industry, foster small and medium-sized parts manufacturers, and support market development	Support for obtaining overseas certifications.
Land, Infrastructure and Transport R&D mid-to-long-term strategy	Fostering the world's leading technology and global enterprises	Support the development of localisation technology for railway components and the establishment of strategies for entering the market
Development Plan of Railway Vehicle Industry	Fostering Small and Medium-sized Parts Companies (Encouraging World's Leading Companies), Creating Domestic and International Markets and Supporting Institutions	Expansion of R&D support focused on small and medium enterprises, support for commercialisation and consulting of development parts, and support for fostering small and medium-sized enterprises (K-STAR project)
Fostering of Small and Medium-Sized Railway Components	Support R&D for small and medium-sized enterprises and joint participation, systematic development of small and medium-sized enterprises and support commercialisation of research results.	

In addition, although the existing railway technology research projects have been focused on improving railway transport power, improving railway safety and convenience, reducing railway construction and operation costs, and upgrading technology of railway materials/parts/devices, a new paradigm shift has emerged for the development research of railway parts in response to successive failures in commercialisation. Therefore, policies are emerging that focus on supporting the development of railway parts and small businesses while shifting the paradigm to parts-oriented development. Accordingly, as shown in Table 20, the KTL outlines the methods for strengthening the technology of railway parts, fostering small and medium enterprises, and expanding the domestic and international markets for railway parts in order to advance technology for the future market of railway parts, along with enhancing the technology for localising and improving the performance of railway parts.

Table 20 The target of KTL by sector (KTL 2018)

Sector	Target	Methods
Railway vehicle	Energy Efficiency Improvement, Development of Railway Vehicle Technology	Development of Energy Efficiency Polarisation Railway Vehicle Technology
	New Technology Applied Railway Vehicle Technology	Securing future leading railway vehicle technology
Railway infrastructure	Energy Efficiency Improvement, Development of Railway Infrastructure Technology	Development of Energy Efficiency Polarisation Railway Facilities
	Securing safety technology and developing interface technology	Securing railway safety technology
Railway maintenance	Development of technologies to maximise maintenance efficiency	Development of Maintenance Stabilisation and Automation Technology
	Securing safety technology and developing maintenance technology	Expansion of maintenance safety technology

Third, in terms of the market environment of the railway industry, according to the European rail industry (UNIFE 2016), The world's railway market has been growing at an annual average rate of 2.6% since 2015, and is expected to grow to about 188.2 billion euros by 2021. Also, the size of the global railway maintenance market is about 40% of the railway market, of which the maintenance parts market is expected to grow to about 72% (UNIFE 2016). Thus, the market can be expanded with the development of domestic and foreign railway vehicle parts and maintenance technology. In addition, the domestic railway test and certification market was a monopoly system of the Korea Railroad Research Institute (KRRI), but as KRRI was designated as a type approval institution after the revision of the Railroad Safety Act, the KTL's sharing of testing and certification tasks led to the KTL's increased position. Based on this, an environment is being prepared to increase the market share rate by strengthening technology consulting for small and medium-sized enterprises. Fourth, if you look at KTL's internal capabilities, it can be divided into human, business and institutional capabilities. First of all, as for human capacity, the railway industry continues to expand, but with the current number of people, business expansion is limited (KTL 2018). The railway system requires professionals in various fields, including machinery/electronic/electrical/control, but the current situation is focused on some areas. Therefore, support personnel are needed to present the direction and strategy of the entire project to achieve the best performance with the optimal number of people. To this end, it is necessary to strengthen VVT expertise and expand the number of professionals in electronic and control fields (KTL 2018). In terms of business capability, the sales and profits of the railway component evaluation centre are steadily increasing at an annual growth rate of 45%, and the continuous increase in R&D tasks and entrusted tasks also makes it possible to predict the continued growth of sales and profits. Finally, KTL is the only public institution in Korea that secures the reliability of test results through systematic test quality control. In addition, KTL is the largest Korea Laboratory Accreditation Scheme (KOLAS)-the designated institution in Korea and can support the reduction of overseas certification barriers and conduct various tests with testing laboratories in various parts of the country.

5.2.2 Background on the testing

Domestic railway technology developers who want to enter into foreign markets must obtain the technology certification which they need. This can cause many difficulties for domestic companies. The reason for this is that there is a variety of demanding processes, such as connecting laboratories abroad and preparing for many of the requirements needed to conduct tests and certifications. As a way to help this, KTL is leading the test in connection with overseas testing agencies to solve the problems faced by companies when testing is impossible in Korea or technical barriers caused by overseas standards. KTL conducts tests in some areas ranging from national infrastructure industries such as aerospace, defence, automobile, railway, electric and electronics to various industries such as medical, cosmetics, and sports equipment. In the case of railways, it is conducting overseas technology certification processes throughout the railway system, including railway vehicles, infrastructure, signal communication, and subway power. The institution verifies necessary matters through analysis of overseas standards and specifications, establishes a comprehensive test plan, supports verification technology for this purpose, and plans and conducts technical testing and certification through consultation with overseas testing agencies. This is intended to help companies advance into the market by securing the verification and reliability of technologies and products developed when they enter the domestic and overseas markets and address the companies' technical difficulties.

Over 2018 and 2019, KTL supported the overseas technical testing and certification process for obtaining European EN and IRIS certification for the railway brake pads of one of Korean SMEs (in this study, it is presented as SB for protecting the company’s information) in conjunction with SNCF-AEF of France and DB Systemtechnik of Germany, respectively. SB is the number one domestic brake friction material company and has been selected as national railway parts support project member. SB is participating as the organiser of the 'Development and Standardisation of Braking Friction Materials for Urban Railway Vehicles' in the government's study on the part compatibility and standard module development of railway vehicles. Its fundamental goal is to prepare standards for braking friction materials and develop standard products to solve the problem of lack of compatibility between railway vehicles. In particular, the company has globally recognised original technologies such as eco-friendly friction material technology, optimal-mixing and convergence technology, and raw material convergence technology that improves safety and wear resistance to environmental regulations in North America and Europe, where regulations are becoming stricter. The two cases to be addressed in this study are the friction coefficient test of brake pads for the entry of upper body brakes into the European market.

For understanding the test, an understanding of the brake-pads test is needed. The brake pad is the component that presses the braking disc in the disc braking system. Materials include non-asbestos, resins, mixed plasticizer of metal powder, or sintering alloy made by heating unique materials, as parts that cause friction and direct braking when contacting rotating braking discs. This is a braking product that is essential for performing disc braking and is a railway product that is responsible for important functions in the braking system. One of the important factors, along with the Compressive strength, hardness, high-temperature stability, and binding force, which are tested to evaluate brake pads, is the co-effective of friction. This indicates the friction on the face where the two objects are in contact, and the lower the number, the more slippery the friction becomes, and the greater the number, the shorter the braking distance. In general, it is the most important element of the brake pad to reach the maximum friction coefficient of the brake pad quickly after pressing the brake pedal. In addition, maintaining a constant coefficient of friction regardless of temperature and speed is also an important factor in the high performance of the brake pads. According to the Korea Railroad Research Institute which made from the Korea Railroad Research Institute (KRRI) (KRRI 2017), the friction coefficient of brake pads is to be evaluated comprehensively by using (1) the instantaneous friction coefficient which is the instantaneous friction coefficient of the braking pad from start to end of the brake, (2) mean coefficient of friction between the braking pad and the braking disc, including the mean of the instantaneous friction coefficient, brake stopping distance, absorption energy, and braking pad compression force characteristics, and (3) average friction coefficient by the speed which is the average speed of the average friction coefficient obtained from the braking friction material performance test results, as well as the basis for evaluating the homogeneity of the average friction coefficient, etc.

In general, pad development tests are conducted in the order of material tests, bench tests, and real-time tests. The friction test methods for the brake pads of railway vehicles are as follows. First of all, the test is conducted under the test conditions specified by the UIC regulations, and the preliminary test needs to be carried out prior to this test. It is largely divided into bench tests and real-time tests. While the bench test is attached to the indoor fixture, the real-time test is mounted on the actual train, and generally, if the bench test is passed, the vehicle test is conducted. If problems occur in the bench test, adjustment/correction/improvement is required continuously. First of all, bench testing has the advantage of being able to test all day and easy to obtain detailed data compared to the vehicle test. Bench tests can produce accurate test results because it is easy to maintain a variety of conditions. It is also easy to grasp the limitations of equipment as it is possible to test in more stringent conditions than the actual situation. Since the bench test under the control of the computer can be performed continuously for 24 hours, durability or performance test can be performed in a much shorter period of time than in the actual vehicle, and even if there is a defect in the product, the test can be carried out without any casualties. For the bench test of brake pads, a dynamometer is used, which is a machine that measures the rotational force and is used to measure friction, power, and energy during rotation. Generally, in the brake-pad testing, the dynamo test is carried out to investigate friction, wear performance, fade performance and noise, in the elation with various questions such as what should be considered is the test conditions, which can vary greatly depending on the conditions, and the sequence of tests also affects the results. Therefore, a combination of a standard test that helps determine a significant development direction by making it easier to compare with a competitor's pad and an additional test that strictly simulates the requirements of the target market will be evaluated (Crolla 2015). If the brake pads pass the bench test, the vehicle test is conducted. These practical test items include legal suitability, performance and endurance test. Tests of stopping distance, steering stability, noise, driving under various road conditions, downhill braking performance, etc. are conducted to test whether they meet the standards prescribed by law, and regulatory standards vary from country to country.

The test and evaluation are performed repeatedly for each stage of development, which consists of testing and evaluating field performance, such as verifying the achievement of development objectives and ensuring the suitability of railway operation. These tests and evaluations of functions are parts of the conformity verification process for product development and acquisition, which helps developers to correct defects by identifying performance levels early in component development while providing data necessary for compromise analysis, minimisation of risk factors, and re-examination of requirements. The test and evaluation may be used as a technical tool to reduce risk factors in the process of developing railway components.

Table 21 Railway Test Centres certified according to EN 17025 and recognised by UIC to perform certification tests of braking components (UIC 2020)

	Brake tests (544-1) and supervision of in-service tests	Pneumatic devices	WSP (541-05)	WSP test rig	Dynamometer (541-3)	Dynamometer (541-4)
CARS	No	Yes	No	No	Yes	No
ČD (VUZ)	Yes	Yes	Yes	No	No	No
DB	Yes	Yes	Yes	Yes	Yes	Yes
FS (Italcertifer)	Yes	Yes	Yes	Yes	Yes	Yes
Ricardo	Yes	No	Yes	No	No	No
MAV[1]	Yes	No	Yes	No	No	No
ÖBB	Yes	No	Yes	No	No	No
PKP (IK)	Yes	Yes	No	No	Yes	Yes
RTA[2]	No	No	No	No	No	Winter tests for composite brake blocks
SBB	Brake tests acc. 544-1 only	Yes	Yes	No	No	No
SNCF (AEF)	Yes	Yes	Yes	No	Yes	Yes
TÜV SÜD Rail[4]	Yes	No	Yes	No	No	No
VR[3]	In-Service tests only	No	No	No	No	No
VUKV Prague	Yes	Yes	Yes	No	No	No
ŽSR	Yes	Yes	Yes	No	Yes	Yes

KTL has identified many testing agencies for testing for the UIC certification acquisition in Europe, and as a result, it has made contact with France's SNCF-AEF and Germany's DB Systemtechnik as the most likely test laboratory. The two laboratories had sufficient conditions to test SB's brake pads, compared with the most recent updates, as shown in the table above. Here, the dynamometer 541-3 was the bench for the brake pad test, the dynamometer 541-4 was the bench for the brake blocks test, and the bench that should be used in the case study was the dynamometer 541-3. As shown in Table 21, both SNCF-AEF and DB Systemtechnik confirmed that both laboratories had suitable conditions for carrying out the SB test.

Before explaining the case study, to explain the method of research, I studied for three years the KTL's participation in overseas technical certification testing. The two tests were the most recent tests done by KTL, with France's SNCF-AEF for the first test in 2018 and Germany's DB Systemtechiknik for the second test in 2019. Through the previous experiences of working on a Korean railroad industry project with KTL, I was granted permission to use the test cases for research by KTL, the organiser of the test, and access information and data.

A brief summary of the KTL and the other organisations involved in the study is shown in the following Table 22. Each institutional position identified during the actual test process can also be found in Table 26.

Table 22 The institutional roles of organisations involved in the study

Organisations	Role in the railway industry	Role in the case-study
SB	Development and sale of railway parts in Korea (braking part), participation in the Korea Railroad Technology Development Country Project	Request for technical test for obtaining European technical certification
KTL	Domestic and international technology development and technical certification support institutions	Support for SB's overseas technical certification examination
Eurailtest	Administrative support for the French technical testing agency	The role of a communication channel with Korean institutions to support technical testing in SNCF
SNCF	French Technology Testing Organization	2018 SB's Brake Pad Test Progress
DB	German Technology Testing Organization	2019 SB's Brake Pad Test Progress
Consultant	Provide local support for Korean participating institutions to communicate with foreign institutions.	Supporting upper body and KTL to communicate with testing agencies while staying in the UK: Coordinating test schedules and the role of resolution and arbitration in case of problem situations

In observing the test, the information and data collection of KTL and related organisations, I collected online data and gathered various documents provided by KTL. This is due to the fact that there is a lack of public literature materials regarding the overseas technical certification test conducted by KTL. The test data that the agency conducted domestically and abroad were not sufficiently organised, and the result data (technical reports) on the two tests were also owned by SB, a technology developer, which meant that in the case of technical results, no details were released to the public. Therefore, in order to carry out this study, I needed to identify, understand, and interpret the collected data through interviews with KTL officials and consultants involved in the test, on business trips or online meetings, adding to the basic information. The questions initially used in the interview to gather data on the overall test are as shown in Table 23.

Table 23 The questionnaire for the first interview and data collection

Step	Main questions	Sub-questions
Pre-test	There are several laboratories in SNCF-AEF/ DB Systemtechnik. How did you select this laboratory?	In the first test, there is also a German laboratory, so why did you decide here?
	Who is selected for the laboratory (how much of the opinion of whom is reflected)? KTL? SB?	

	Pre-requisites for testing: After deciding on a test laboratory, for this test, who prepares what? (requirements)?	• Requirement document • Input from the customer • Project plan
	How do organisations prepare for the detailed contracts they want to obtain after the test?	
	How do you schedule it?	
	How is the price set, and when is it paid?	
	Who points out and contracts with overseas consultants? (Where do they belong?)	
During test	Do the people involved have meetings for the main test?	When did the meeting take place for the first and second tests?
	Did the test go according to schedule?	
	What tests have been carried out? (Test name/date/period/contents/number arranged in table)	• Bench test
	Did you ever find any problems during the test?	
	If you had a problem, what was it, and who and how did you solve it?	• Problems with communication (regime & landscape-level)? • Problems with technical faulty (niche-level)? • Problems with the process faulty (regime-level)? • Problems with the extra environment (landscape-level)?
	How cooperative was SNCF-AEF/ DB Systemtechnik? How efficient was the test process conducted?	What is the satisfaction level for KTL and SB?
Post-test	Did SB, KTL, and overseas consultants achieve the desired purpose?	The test process has been done enough as contracted, and have you got everything you want?
	What is the post-test certification process? Which organisation participates in European certification and issues	

	certificates after testing? What certification does it get and what effect does it have?	
	To what extent did SB and KTL communicate?	To the test lab? To the certification body?
	Were there any problems that were discovered during the test process? What is it?	
	If you ask the laboratory again, what do you want to fix or add?	
	How can the test process be evaluated from the perspective of each person concerned?	

5.3 Case 1: Testing with SNCF-AEF

For technical tests to determine if the SB's brake pads conform to European specifications, KTL made a contract with an overseas consultant, and then they let him know about the aims and contents of the SB's brake-pads test for railway vehicles. From then, both KTL and an overseas consultant started to communicate closely for preparing the test. At first, they selected two testing centres which are SNCF-AEF and DB Systemtechnik among many European testing centres to compare their capabilities for the test of SB's brake-pads, then visited those two centres to collect detailed information, such as the test conditions and schedules of both German and French laboratories, the technical competence to conduct the tests, the possibilities of each of their strengths and weaknesses and other related parts, etc. Although the comparison results between the two laboratories were almost similar, the fact that SNCF-AEF was more active in one of the most important parts of the test schedule led to the first test with SNCF-AEF.

The following section describes the actors, schedules and contents of each test. The section has been researched based on basic information and data, also adding data from interviews with KTL and overseas consultants who took part in the processes described. The details of the interview are attached in the Appendix. I divided this content into three as the pre-test, during-test, and the post-test. The main schedule for this test was as shown in Table 25.

Table 24 The schedule for the first test with SNCF-AEF

Test	Date	Schedule
The first test with	13/09/2018	An open meeting of braking pad test (check for a plan such as a test outline and schedule)

SNCF-AEF (2018)	14/09/2018-19/09/2018	Troubleshooting as a result of technical issues (delayed production of brake discs)
	20/09/2018-28/09/2018	UIC 541-3 Test carried out following Appendix C.3 & C.4 (using SNCF-AEF dynamometer)
	30/11/2018	Issue Test report

5.3.1 The process of Pre-Test with SNCF-AEF

KTL, SB and an overseas consultant visited SNCF-AEF in September 2018 for preparing for the test. They had an open meeting for the braking pad test to confirm the plan, including the test outline and schedule. The first purpose was to check the dynamo of SNCF-AEF which will be used for the test. The second purpose was to understand the business relationship between Eurailtest and SNCF-AEF. This was important because when the test starts, KTL, SB and an overseas consultant need to clearly understand the boundary of responsibility of both Eurailtest and SNCF-AEF. The third purpose was to know the testing cost with the testing schedule and condition.

Visiting SNCF was successful. KTL, SB and an overseas consultant had a meeting with engineers and managers of Eurailtest (2 people) and SNCF-AEF (5 people) and the result of the meeting is as follows. First, the dynamo owned by SNCF-AEF was appropriate for the test of SB's brake pads. Second, to make a contract of the test with SNCF-AEF, it was necessary to contact through Eurailtest. It meant that KTL, SB, and an overseas consultant should discuss and negotiate with Eurailtest first, then Eurailtest associated with SNCF-AEF to make a final decision. After that, SNCF-AEF conducted the test by taking a whole responsibility. Therefore, KTL, SB, and an overseas consultant can contact SNCF-AEF when they need to discuss specific parts or issues that occur during the test. Third, the date on which SB wants to take the test and schedule were made available.

During the test, there was an intermediate organisation, Eurailtest, that connected the two sides. It will be introduced later when compared to the second test, but it was the biggest difference when comparing the two tests. So, instead of communicating directly with the laboratory, all of the problems to be discussed, conversations, and requirements that occurred during the test were conducted in a way that went through Eurailtest. This made KTL, SB, and an overseas consultant think advantages and disadvantages theoretically. They also had questions about the pros and cons of the actual test because of this communication system. The reason for distinguishing between managing and progressing the test is to ensure that the commercialisation of technology is taken by marketing professionals and engineers focus on technical tests only. However, in the perspective of asking the test, there are possibilities to increase the testing cost and ineffectiveness in communication twice with both Eurailtest and SNCF-AEF.

In the first phase of the pre-test, because SNCF-AEF did not show an active attitude in the contract even though SB decided to test with SNCF-AEF, the consultant revisited Eurailtest and SNCF-AEF to meet with the SNCF-AEF engineer in charge of technical testing and to discuss more technical issues with them. All this was delivered to SB, and the person in charge of the Eurailtest was always present. Overseas consultants handled arrangements and communication related to visiting SNCF-AEF, and the entire technical interpretation at the meeting was also conducted by an overseas consultant. As a result, KTL and SB's participants were able to communicate without language barriers.

The preparations for the test, i.e. the requirements of the laboratory, were as follows. First, for the test, the upper body brake pads must fit the test machine (disk machine) of the SNCF. This means that the test can only be performed if the specifications are correctly prepared, so it had to be prepared first. Even if SNCF has disks according to various specifications, it was necessary to prepare specifications required by laboratories as much as possible because of the potential for unexpected fluctuations (specification of brake pads). The second was to inform the exact purpose of the test. The exact purpose of the test is to ensure that the test conditions, processes, costs, and schedules are accurately determined. The purpose of the communication is to be fundamentally UIC-certified, but the UIC-certified standard is so high that it is assumed that ultimately two or three more tests may be needed to be certified, with the expectation that there will be many complements to the product at the time. Therefore, rather than expecting to be certified by this test, SB and KTL focused on identifying the problems of the product through the test. In other words, the purpose of the test was to have a stronger aspect as a technology development purpose, which was to use it as an opportunity to more clearly know what the results or responses were when tested locally and what should be supplemented. The third was to make sure where the brake pads were to be tested, whether they were for high-speed railways, trams, general railways, and their use. This is because the technology, machinery, duration, and cost of preparing the test vary depending on the application, and the measurement figures and complexity required by the test results vary greatly, which is essential for accurate testing. Fourth, the material composition of the brake pad to which the test is requested should be informed. There are reasons why the numbers entered in the preparation of the test vary depending on the material. However, in the case of products that contain a lot of heavy metals in terms of the environment, the import and export will be restricted from the time they are sent to France for testing. Hence, SB and KTL had to inform the laboratory of what materials they used. Therefore, it was necessary to prepare and inform the test results/ contents of the brake pads in test results/ contents. Besides, the SB had to inform the requirements concerning the desired test schedule, availability of test attendance and filming, and whether raw data could be separated. As the terms, costs, and duration of the contract vary, all requirements had to be made clear to the laboratory before the contract.

5.3.2 During-Test with SNCF-AEF

SNCF-AEF was requested to conduct a bench test for one type of brake pad. All the requirements were prepared during the pre-test. The SB's primary purpose of the test is the learning the testing of advanced European technology and process. Therefore, KTL supported and supervised the entire test process for the sake of imagination and wanted to manage the test process by focusing on attending technical tests. Along with this, the consultant also tried to focus on facilitating the entire test process by helping clear and efficient communication.

The test was not carried out as scheduled due to a delay in the production of the disc for the test installation and testing. However, this was subsequently resolved and the test was abled be carried out in late September. The test was conducted using the dynamometer of the laboratory in accordance with UIC 541-3 Appendix C.3 & C.4. This UIC's dedicated guide for the certification of friction test bench describes the procedure for obtaining UIC certification through friction test bench, including requirements to recognise the performance of brake pads used in international transportation. KTL made efforts to understand this in advance before the test in order to carry out the test smoothly and effectively and successfully and continued to carry out verification work during the test process.

Overall, the tests were carried out on schedule. However, there was a problem that the test was not carried out as scheduled because the disc device was not prepared in time for attaching the test product, which was ordered by the testing laboratory, but it could be solved by the efforts of the relevant agencies. This will be discussed in more detail in Chapter 6.

5.3.3 Post-Test with SNCF-AEF

After the test, SB received a report on the test result from the laboratory, including raw test data, which was promised during the process of coordinating due to the delay of preparation during the main test. Based on this, SB identified the level of its technology for European certification and had the opportunity to use it to prepare products for the following certification. KTL had the opportunity to analyse and organise the communication system used in the test and develop it into a more effective method of communication in future tests.

5.4 Case 2: Testing with DB Systemtechnik

SB was satisfied with the results in the first test. The process and results were generally satisfactory, except that SNCF-AEF was unable to prepare the disc on time and had problems with the observation. Thus, because the continuity of the testing organisation, i.e. the SNCF-AEF, was the first test, the second test was decided to proceed with the same institution, and in 2019, it attempted to communicate with the SNCF-AEF to conduct the second test. In the process, SNCF-AEF officials did not carry out as much communication as expected, so three to four months were spent fruitlessly. SB had a schedule to complete the second test within the specified project period, and SB contacted them in consultation with the KTL and the consultant to conduct the second test with DB Systemtechnik in Germany. DB Systemtechnik agreed to test SB's technology within the desired period after meeting and consulting with the upper body, and so the second test was conducted by DB Systemtechnik. Price played a major role in making this decision. When the initial test was chosen as SNCF-AEF, there were many price differences at the request of the SB, but the decision was made as required by the SB, whereas the much cheaper DB Systemtechnik offered test price was an attractive condition for the KTL when it was quoted for the second test in the above communication environment. The main schedule for this test was as shown in Table 25.

Table 25 The schedule for the second test with DB Systemtechnik

Test	Date	Schedule
The second test with DB Systemtechnik (2019)	16/09/2019	Brake pad certification test commencement meeting (consultation on the detailed schedule of testing and evaluation)
	17/09/2019-23/09/2019	Test item A (Code name CH 22) test carried out (Test according to UIC 541-3 Appendix C.3 & C.4) Test item A review test results and determination of follow-up test items (Code name CH28, Type 1 of CH30)
	09/24/2019-09/30/2019	Test item B (Code name CH 30) (Test carried out according to UIC 541-3 Appendix C.3 & C.4)
	04/02/2020	Issue test report for test item A
	18/02/2020	Issue test report for test item B

5.4.1 Pre-test with DB Systemtechnik

In the middle of September 2019, KTL, SB and an overseas consultant visited DB Systemtechnik for consultation on the detailed schedule of testing and evaluation. Similar information and documents were required from the first test, such as the products to be tested, test purposes, test schedules, component analysis data of products for testing, etc. SB and KTL prepared all the essential information and test requirements that DB Systemtechnik needed to prepare for the test, and the consultants who received the desired schedule from them proceeded to coordinate the entire test schedule through a meeting with DB Systemtechnik. In the case of DB Systemtechnik, the preparation process for the test was relatively smooth because, unlike SNCF, the disk devices needed for the test were not required to be purchased separately.

5.4.2 During the test with DB Systemtechnik

Unlike the first case, SB wanted to test two types of brake pads this time. In the second test conducted by DB Systemtechnik, SB and KTL planned to prepare three products and test the first one, and depending on the results, and they planned to test one of the other two products. First, test item A (Code name CH 22) was tested from mid to late September 2019. The test results of this product could be verified immediately after the test, and test item B (Code name CH30) was tested among the other two products. At this point, the second test item was decided based on the test result of the first item.

SB wanted to see which of the two products was closer to meeting the UIC certification standard, acknowledging that SB still lacked its skills to match the UIC certification standard. Although there were results from the bench test in the SB's own laboratory and SB already knew which was relatively better, it wanted to know which results from the bench test at overseas laboratories connected to the UIC certification authority. Therefore, two types of brake pads were tested, and the more capable brake pads were tested first. In SB's own laboratory tests, better technical brake pads could, of course, be expected to produce the same or closer results at DB Systemtechnik's labs. But more importantly, SB wanted to see how the test data at the two labs would differ. This was due to the fact that it was a good way to know the degree or level of SB's technical testing facilities and measurements compared to world-class laboratories.

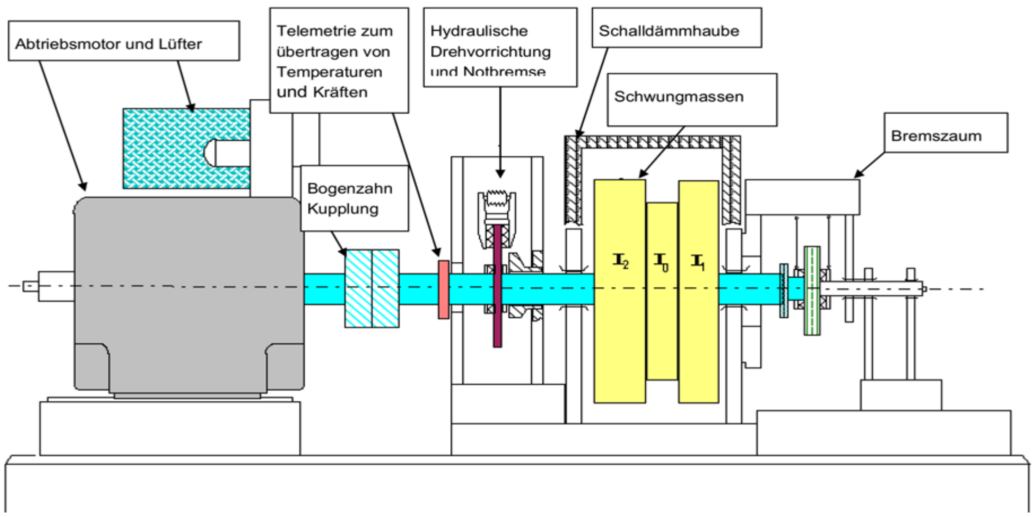

Figure 15 Construction of the test bench overview (Meier 2019)

The process for preparing the test in the DB Systemtechnik test centre was carried out just like the test with SNCF-AEF based on UIC 541-3 Appendix C.3 & C.4. Using the test bench which can be seen in Figure 15, DB Systemtechnik attached the SB's brake pads on the brake disk and tested with the following contents: Coefficient of friction curve, temperature profile, braking force, tangential force, tread roughness, wear, deformation, temperature stress, break-away tests. The overall schedule went ahead as planned, and support for the laboratory's observation was also cooperative. The test proceeded satisfactorily, and with both wet and dry-test of the two types of brake pads, although the test period was more time-consuming. Moreover, it was able to obtain many technical interpretations relatively. Furthermore, DB Systemtechnik provided raw data quickly whenever the test process was carried out, which was frequently checked, and it was effectively used to determine whether other types of brake pads were to be tested in the following order.

Overall, the tests were carried out on schedule. However, there was a delay in the schedule due to a situation in which the test machine needed to be repaired at the test laboratory at the beginning of the test, but it could be solved through the efforts of the relevant agencies. This will be discussed in more detail in Chapter 6.

5.4.3 Post-test with DB Systemtechnik

The final test report was issued later than scheduled due to a delay in the schedule. It was because of a situation that the test machine had to be adjusted during the test process. It was planned to receive the test report in 2019, but it was delivered in February 2020. However, it was not a big problem for SB and KTL, given that they were able to check the data on the results in the middle of the test process. Although they did not receive certification because the tests' results did not meet the UIC certification standard, SB was satisfied with the results. This is because SB was able to get the results data and confirmed that its own testing results which have already been tested in SB's testing laboratory are not far from the European standard. KTL also made and confirmed a useful communication system for cooperation with overseas testing agencies. It is important to not just have a learning process to correct the problems identified in the test, but it is also crucial to develop the flow of the process with the improved communication and knowledge transfer which can be useful for the future.

5.5 Chapter Summary

The researcher has gained deep access to the practice of overseas technology certification, especially for the two specific cases. However, I experienced limitations as the data collection of the activities of other actors could not be made directly, hence I was only able to collect secondary data from KTL and the consultant. Moreover, where it was impossible to conduct interviews with limited actors to observe the test processes, these deficiencies could largely be filled by the various responses provided by KTL.

In summary, KTL's network for overseas technology certification tests was successfully established and operated regarding the test progress and results. The problems found during the process were all solved with the understanding and cooperation of the actors involved and the operation of a sufficient communication and knowledge exchange system. Furthermore, in terms of KTL’s goal attainment, it can be seen that KTL has achieved its aims. First of all, KTL successfully helped SB to achieve its aim to verify the level of technology of its products. Therefore, the most fundamental purpose has been achieved. Moreover, KTL used different communication systems in the two tests, and after supplementation, it was possible to confirm that the communication systems used in the second test were useful and that this system could be used later. This is what KTL wanted to confirm through the test process, so KTL was able to achieve its purpose while enabling the researcher to observe multiple different challenges and different ways to solve them.

Based on the observations in this chapter, the next chapter will provide a deeper understanding of the network construction and operations, communication and knowledge exchange (transfer) systems, and the problems that have occurred, along with their solutions. By doing this, we may find how they could implement such systems in practice in the future.

6. Findings and Analysis

According to Van de Ven and Garud (1993), Innovation is defined as the process of discovering and implementing new ideas through communication and networks between people as the institutional environment changes over time. Based on the various definitions of innovation, Song (2006) explained that interaction between innovators in the process of expanding their innovation ability to derive innovation results through interaction between the innovators' work-routines and the subjects. In addition, it can be said that this is a kind of communication and exchange, which means the degree of the intimate relationship between the parties involved or the agencies concerned, and that the related parties or agencies with different information and capabilities contribute to the growth and development of the innovation process by harmonising the information and capabilities with each other (Jaworski and Kohli 1993). For innovation results, the way in which the innovator performs innovation activities (termed 'Routines'), the interaction activities between the innovators are important, and effective innovation outcomes can be derived when an organisation and institution structure is established to develop and commercialise technology more effectively than the technology development would achieve if unsupported (Song 2006). Scholars cite the exploration of new directions, creation of ideas and strategies, learning from discoveries, a balance between various perspectives, and composition of innovation networks as the main features of this innovation process. Innovators and those involved with these characteristics interact to create new knowledge and ideas and carry out the embodiment appropriate to their implementation. (Dewar & Dutton, 1986; Van de Ven, 1993).

The purpose of this chapter is to clarify how KTL has been working to acquire European technology certification for domestic technologies in the process of such innovation, analysed through the MLP. Therefore, the areas to be identified in this chapter are as follows. First of all, who are organisations in this case at each of the three levels? Did organisations perform the role of the position placed by the researchers? In addition, as an actor at the regime level, how was KTL able to communicate with other organisations to achieve the expected effect? This research focuses on KTL and examines its relationship with other organisations. Questions included: How did the KTL interact with related organisations on two tests, with what communication system? What kind of experience has KTL had in exchange according to the types of knowledge KTL has? If there was a problem, how did KTL defeat it and how? Which outcomes could KTL get from the test? Finally, by confirming the answers to the previous list, this chapter aims to understand whether KTL has played an essential role in the development of Korean railway technology and acquisition of overseas certification and how KTL has played its role as a regime level actor in the MLP framework.

To this end, the location and role of each institution in the MLP framework were first identified, and then activities for communication, technical knowledge and information exchange with each institution of the KTL were analysed. It describes the following: the impact of communication, progress and results on the testing process between the KTL and related agencies, the differences and commonalities of technology knowledge and information exchange methods found in the testing process and results, the technical knowledge exchange, transfer and guidance, and the various test environment changes that KTL has been challenged and resolved.

6.1 The Role and Relationship of Institutions Using the MLP framework

The fields of science and technology base, technology development and transformation are closely related to knowledge and networks management. According to Powell and Grodal (2005), as the ability to effectively handle knowledge has become more critical than ever in economic growth, various collaboration across organisational boundaries has become common among the various actions for innovation and its success. The importance of network building and management is also emphasised. An organisation's network is a means for an organisation to share or exchange resources and jointly develop new ideas and technologies, and as advances in science or technology evolve rapidly, and many people share various information and knowledge, a single company cannot have all the skills and knowledge necessary to bring about important innovation (Powell and Brantley 1992, Powell, Koput et al. 1996). Thus, various networks have become the necessary ways of establishing the innovation process, and this study has also identified two networks of testing processes supported by KTL using the MLP framework.

Table 26 The position of the actors in the testing process

Actor	Position in the testing process
UNIFE	Organization for European Technology Certification
UIC	Organization for European Technology Certification, Technical Certification Guide Production Agency
KTL	Korea's Technical Test Support Institutions
DB Systemtechnik	Technical Test Laboratory (Germany)
SNCF-AEF	Technical Test Laboratory (France)
Consultant	Coordinator of overseas technical testing laboratories and Korean institutions
SB	Technical Test Support Request Authority (client of KTL)

The main actors of the tests covered in this study may be summarised as shown in Table 26. The tests that KTL conducted were in connection with overseas technical testing laboratories in 2018 and 2019.

SB wanted to conduct a bench test for selling the brake pads of railway vehicles to the European market. Through this, SB could confirm its technology's stability and excellence and expand the scope of product sales at home and abroad. This leads to the company's profits. This test was conducted under the leadership of the KTL as the Korean government's R&D program, so the test processes costs were paid to the overseas testing agency by the Korean government. Also, this can be a way to solidify its position as an institution supporting national policy-related projects, in connection with national policies supporting technology development. In order to conduct effective and efficient technical certification tests abroad, KTL has been able to reduce the use of unnecessary time and expense, obtain professional advice from using overseas experts, and create smooth communication and relationships with overseas certification bodies. Collaboration between agency officials who are familiar with the overseas situation and professional consultants who communicate with and coordinate schedules with testing agencies in a closer geographical location can facilitate the progress of the more favourable testing and certification process. From the perspective of French and German test labs chosen by KTL as test institutions, helping them accurately judge Korean companies' technologies with their superior technology, not only can they be recognized for their excellence in testing skills and raise their awareness. It can be an effective way to expand the testing and certification market in the country and internationally.

With these potential benefits for each institution, the detailed aims of the participants follow. SB wants to achieve a UIC accreditation certificate through passing the brake-pads testing, and if not, SB wants to know what problems they should solve and improve to pass the test. Also, SB aims to improve the capability to develop their technologies by observing the testing process of advanced test centres overseas. On the other hand, KTL aims to manage the testing of SB’s brake pads successfully because SB is KTL’s client. Also, KTL wants to understand the whole testing process to effectively conduct or manage the future testing process. For overseas consultants, both SB and KTL are clients. Therefore, the aims of overseas consultants’ are to help the test process smoothly by delivering demands and requirements between SB, KTL and overseas’ testing agencies to lead the successful results. In the last, overseas’ testing agencies aim to deliver correct results to SB by conducting an accurate testing process.

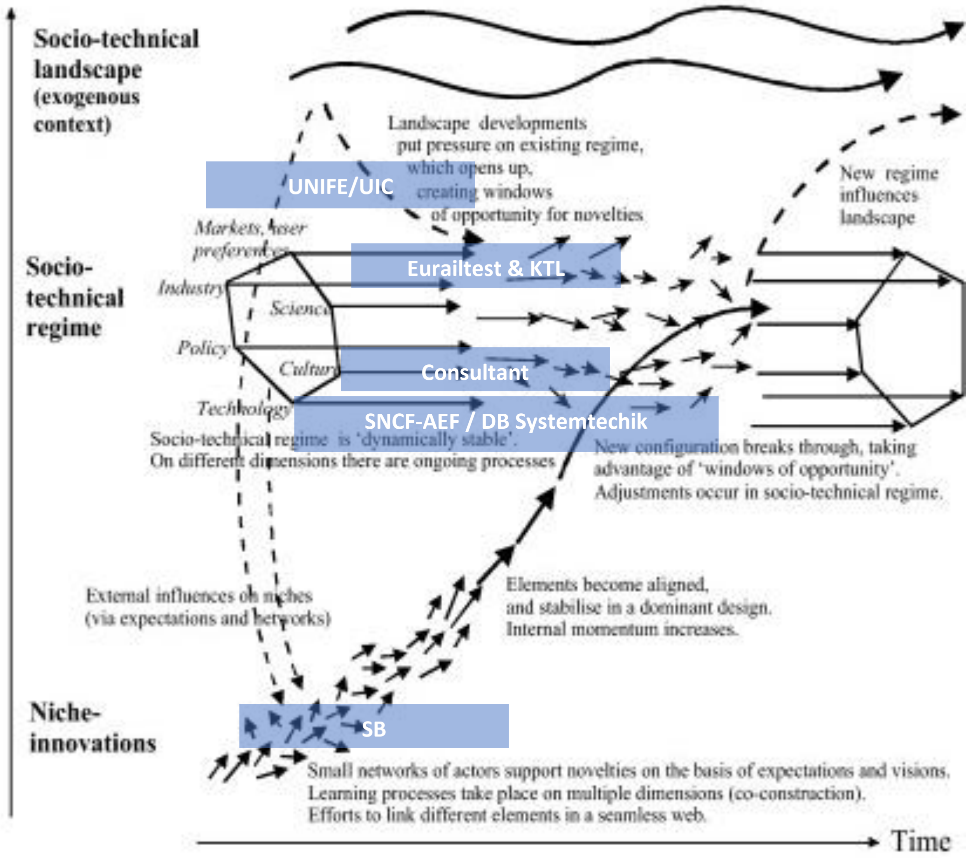

Figure 16 The network in tests based on Multi-level perspective on transitions adapted from Geels (2011)

Figure 16 illustrates the role of the agencies involved in these two tests. In the figure, each organ can be placed at the following levels: First of all, UNIFE and UIC can be placed at the landscape level in terms of different perspectives. However, in this study, these organisations are located at the regime and landscape level. The UNIFE is the institution that certifies. UNIFE, one of the supporting bodies of the European Railway Agency and the European Railway Research Advisory Council (ERRAC), studies interoperability standards and coordinates EU-backed research projects that strive for technological harmonization of railway systems. This organisation is not a perfect landscape-level fit either, as it is ultimately under the influence of the government. However, to some extent, it was deemed to be a higher authority to place in the regime, so it was placed between landscapes and regimes. The focus on providing strategic and operational knowledge to UNIFE members is close to Regime level activities, where aspects such as policy initiatives and system building are commensurate with landscape-level activities, leading the European railway industry through innovation, quality maintenance and improvement through advanced research.

Additionally, the UIC is another organisation that is involved in the two tests but did not need direct contact except for the verification of the certification process in the second test. This agency's role is involved in standardisation and improvement related to the operation and construction of railways, where laboratories and the institution they intend to test are studied and provide various technical guidelines that should be followed as guidelines during the testing process. In particular, UIC-leaflet, which is the UIC's solution, is a reference to the various technical specifications of the Member States. The agency's main activities, such as promoting international cooperation related to railways and developing innovative programs, show that the agency is under the control of the government, but has influenced such as restricting or guiding the activities of other levels' actors. Thus, in this study, like UNIFE, it can be seen as an intermediate step in landscape and regime-level. Also, given the relationship between these two agencies and the regime-level institutions, their activities and objectives have a lot of influence on actors related to the regime-level technology, policies and markets, which are closer to a vertical relationship rather than a consultative relationship.

For the first test, mainly five actors are involved, such as Sanshin Brake (SB), KTL, consultant, Eurailtest, and SNCF-AEF. The first test case shows that each actor has the above position in the MLP framework. The institutions mentioned in the case study are mostly regime-level institutions, except for SB.

When these actors are placed in the picture describing the model of the MLP, SB is a niche-level actor that develops the technology. SB is a company that research and development technology components, mainly brake equipment, located in the lower part of the model in the technological niches. SB is a commissioning agency for this test, with the aim of developing railway technology and components. It has its own research institute, and it also has the ability to test and check technology development. In order to obtain technology certification to commercialise its technology in Europe, the company wanted to test its technology at testing laboratories in Europe using the government's overseas technology certification support project organized by KTL. To this end, SB had to cooperate with various institutions, selecting KTL as an institution supported by Korea, and connecting it with each testing laboratory in France and Germany as an institution that wanted to receive support in Europe. In conjunction with the niche actor described in Chapter 2, the niche actor appears in places such as projects supported by technical research institutes or other agencies (Geels 2012), with aims to become mainstream by disseminating new technology ideas. Also, government policy or support is important to help innovation and development at the niche level (Geels and Schot 2008, Hielscher, Seyfang et al. 2011). In light of this, it can be seen that SB is consistent with its objectives for technological development and with respect to dependence on government-funded projects. Based on the support of the government or related agencies, SB actively prepared and responded to interactions with the agencies to conduct the test using external help as much as possible. The external agencies involved here are located at the regime level.

At the regimes-level, reactions to new technologies appear. First of all, the KTL, consultants, Eurailtest, SNCF-AEF in the first test, and DB Systemtechnik in the second test play their respective roles, resulting in the acceptance or elimination of SB's technology. As mentions earlier, regime actors include all actors involved in systems in various sectors of society, including markets, industries, science and technology, culture and policy. At the regime level, the laboratory of SNCF-AEF or DB Systemtechnik can be placed first. They are responsible for the role of science, technology, and market regimes at the regimes-level, as they operate laboratories and support certification tests' progress to ensure that technologies born and developed at the niche level are accepted and settled in the mainstream.

Since SNCF-AEF and DB Systemtechnik are organisations that conduct technical testing directly, the test results from these organisations help to determine whether SB's technical products can be recognised or not. Being approved between SB's products in the European market means that niche technology can join the mainstream, which has to do with whether SB's brake pads can gain places in many markets and generate new technology shares if they demonstrate excellence. Also, they could be placed as market regime actors, as they are internationally leading organisations in an unrivalled position in the technology certification industry. This can also be seen by the size of the organisation and the size of the clients of these testing agencies (such as how many well-known companies are their clients). In other words, whether or not many railway-related companies, both qualitatively and quantitatively, are involved with these laboratories and are requesting technical testing, allows them to identify the impact they exert on the certification market, including users. Therefore, it can be seen that the two test institutions are engaged in market-regime activities.

As explained in Smith, Stirling et al. (2005), problems may arise during these activities because of conflicts with actors who maintain existing rules, theories and systems and those who wish to introduce new changes, but the problems found in this study are solvable through understanding and consultation between relevant agencies. Moreover, the widespread interaction with other actors by sharing resources and using the network was also a part of the investigation into network and communication. This will be introduced in the following sections.

Eurailtest and KTL also occur at the regime level because they connect and support testing agencies with SB. The KTL is technically in the middle of niches and regimes-levels. In terms of its role in Korea, it is clear that it corresponds to a certain level of regimes level, and its location, in the country where the test is conducted, is in the middle of the two levels. In the case of the technical certification test used in this study, it can be seen that KTL belongs to the science and technology, policy and market regime. KTL is an institution whose main task is a technical support project, and it can be seen as serving as a regime for science and technology because it has engineers who can understand, interpret, and deliver the contents when observing technical tests in overseas laboratories. It also plays a role in expanding the market for the certification industry, so it can be included in the market regime, and above all, it includes the role of the policy regime, because it is the Korean government's support policy implementation agency.

Also, Eurailtest is regime-level, particularly policy and market regimes. Its role for the test is managing railway technology, dealing with policies related to railway technology and certification regulations, and dealing with technology markets in Europe. This is because the agency's role is to connect and manage companies seeking technical certification tests in France to appropriate laboratories. Direct testing is handled by SNCF-AEF, but it must be done through this agency in order to be tested in France, which serves as a regimes-level for technology, policy and markets, given that they provide and manage technology test markets based on laws and regulations related to it. Eurailtest and KTL involve activities that are linked to markets and policies. This is because it is in some ways related to domestic and foreign policy-making agencies to support certification tests. For example, Eurailtest communicates with UNIFE and associated agencies that create guidance or policies on technology certification in Europe and actually certify the tested technology. KTL is a country-related institution that is somewhat affected by government policies. Therefore, its activities are closely related and influenced by various policies. The overseas consultant is also placed at the regime level, as he (in the case of this study) can be seen as being in a middle position rather than being seen as a full regime-level. The overseas consultant has the characteristic of an agency that communicates and coordinates the communication with KTL and SB to overseas testing laboratories.

The consultant locates at the regime level. It has an agency personality that communicates and coordinates the results of communication between KTL and SB to overseas test labs. The consultant can be located in the culture and technology regimes because the consultant's primary role is to adjust and mitigate problems caused by linguistic or geographical factors in communicating with foreign institutions and to the extent that the engineers and technical parts of the laboratory can be addressed. In the first test, the role range of the consultant was close to the middle of the niche and regime-level, as well as the SB of the niche-level, but in the second test, it was included in the action of regime-level as a change in the role range. As further elaborated in the analysis of communication, the role of consultants was further enhanced in the second test process than in the first one, and the inefficiencies in the first test were reflected and supplemented in the second test. During the second test, the role of the consultant expanded and became more independent, as a network structure focused more on communication with overseas testing laboratories was established.

Thus, the actors located in the MLP framework participate in each test through the following processes. In the first test, which took place in 2018, at the request of SB, KTL surveyed and screened overseas test laboratories and discussed with SB and the consultant to select the laboratory. After signing a contract with the laboratory through Eurailtest, Eurailtest was given the role of the middleman and connected SNCF-AEF to KTL and SB during the whole process. SNCF-AEF conducted the test with the requested test details. While the laboratory's engineers supported all the technical details and issues, the administrative work was undertaken by Eurailtest. The consultant took the role of supporting the overseas activities of the Korean participants. These actors' locations in the MLP framework were able to be defined as follows: KTL was responsible for the technology, science, policy, market and industry regimes on the Korean side, which enabled it to support niche technology, and the consultant was an actor for culture, technology and policy-regimes and he delivered the Korean side's point of view to Eurailtest and SNCF-AEF. SNCF-AEF played the role of technology and science-regimes actor, whilst Eurailtest took on the role of policy, markets, and industry-regimes actor.

Shifting the focus to the second test, which was carried out in 2019, similar to in the first test, KTL supported the test by connecting SB with the test laboratory, DB Systemtechnik. In preparation for the second test, KTL contacted the UIC headquarter to discuss specific procedures for obtaining the UIC certification and other expenses. However, unlike in the previous test, the consultant played a slightly different role. Although he still took on the role of connecting and supporting KTL with overseas test labs, in the second test, the range of his role was reduced and the importance of his role was increased. This was due to the role of the consultant changing to be responsible for most of the communication with DB Systemtechnik. DB Systemtechnik conducted both contracts and tests directly without any intermediaries, and except in particular circumstances, communicating with the consultant mostly. In this second test, KTL is again responsible for technology, science, policy, market and industry-regimes on the Korean side, allowing it to support the niche technology. The consultant took the role of the culture, technology, and policy-regimes actor. Dissimilarly, DB Systemtechnik was the actor for technology and science-regimes and market, industry and policy-regimes, allowing it to gain authority over overseas activities.

Powell, White et al. (2005) have found that in the science-centric field, it is often the case that organisations that develop relationships with various other organisations and perform activities play a central role in the industry network. According to Geels (2012), the niche innovation, which is supported by more actors and resources, has a higher level of driving force. In regards to these, it can be said that SB's technology products receive a great deal of support from various actors, such as KTL, consultants, overseas test laboratories and connecting institutions, and the Korean government, in developing technology and acquiring certification. Therefore, it also can be said that it has a higher quantity and quality of driving forces than companies that do not have such resources. Furthermore, having such support allowed SB to be linked to a network, involving domestic and overseas institutions, which was created by KTL in order to facilitate the certification test process, and a communication system suitable for the network was also created and used for the test. On its own, it would have proven difficult for SB to build its network, which involves such a diverse range of actors, including the Korean government, KTL, overseas technology testing agencies, a consultant who helps to contact the actors of the network, and UNIFE if the test results meet the UIC-level. Therefore, in accordance with the size and quality of the network, the achievable technical knowledge and information are expected to also be of high quality and can be predicted to provide a fairly high level of propulsion in terms of quality. Furthermore, in terms of communication systems, KTL provided support by adding a system that is designed for SB's technical testing on top of the communication system that has already been built up by cooperating with various domestic and foreign test laboratories over many years. Moreover, KTL supplemented and developed the communication system of the first test to use in the second test more effectively. Through this, it can be assured that KTL's supporting activities are made to qualities of high level, allowing high-quality driving forces to be developed in niche technology and innovation.

6.2 KTL's Activities for Building-up Innovation Process: Communication

After understanding this basic structure, the location (level) and the role of the organisation, to learn more about communication, which is part of the innovation process, an interview was conducted to confirm the details. It was not easy to derive experience from the position of being involved in the test, but following the flow of questions and finding out opinions about them was the most important part of this study. In general, it is known that the qualitative review provides more validity for answering questions and helps to understand complex organisational realities by providing rich insight (Eby, Hurst et al. 2009). To this end, researchers should design interviews so that their data collection and analysis can be transparently explained and justified in relation to the purpose (Baker and Edwards 2012, Robinson 2014).

It was helpful to use coding to draw up problems as a way to identify the direction of the question being asked, and there are three steps to coding. First of all, open coding is an analysis process that finds concepts (code) of data and phenomena observed during qualitative data analysis, and axial coding is an analysis process that correlates concepts investigated in open codes with each other through a combination. Moreover, selective coding is the final step in data analysis, in which the key concepts presented in open codes are identified and then completed through axial coding (Williams and Moser 2019). The steps were taken using coding to identify the hypothesis to be identified as in Figure 17.

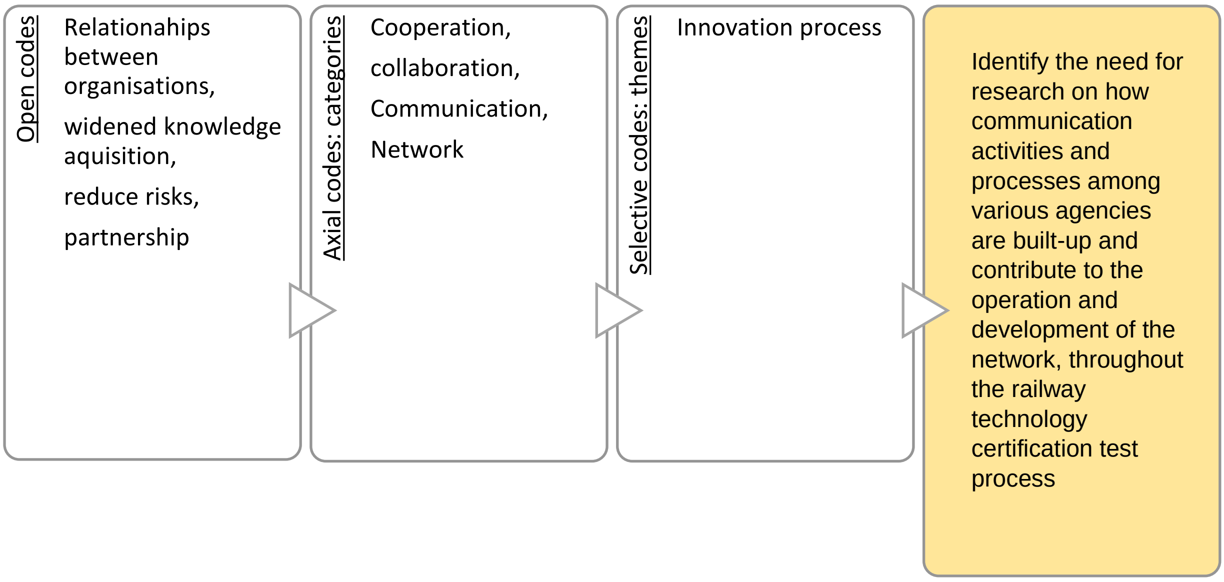

Figure 17 The flows of information and result in networks of each testing

First of all, in open coding, the concepts found in the literature review can be included such as relationships between organisations, widened knowledge acquisition, reduce risks, partnership, etc. In the axial coding phase, the preceding concepts can be grouped into related ones and classified as co-organisation, collaboration, communication and network. Then, in selective coding, all of this can be arranged into an innovation process. Here, I was able to study the question of how communication between various institutions, which we would like to confirm through this case study, is built-up and contributes to network operation and development.

To find out this, I conducted a preliminary investigation and an interview with an official, which included the following questions: What did you communicate with each institution in the two pre-test courses, and how can the KTL evaluate the process and results of these communications? What were the differences or distinctions that you felt while communicating with each institution? Do you think any of the communication methods experienced in the two tests could be helpful for the next test? What are they? The reason for interviewing these questions was to confirm that KTL can make continuous technical certification support projects into knowledge that can be used as it develops and develops by experiencing various communication systems for each institution during the two test experiences.

Looking at the communication system during the first test process with SNCF-AEF, SB, which commissioned the technical test, fully consulted with the KTL on the test schedule and contents and entrusted the progress to the KTL. According to the system of the first test, there was a stage where SB had to sign a contract with Eurailtest directly as a client in preparation for the test, at which time after the two agencies signed the contract, KTL entered the intermediate coordinator and played a role. However, after SB, consultant, and KTL communicated together in the entire other processes, the consultant operated a communication structure in which the consultant contacted the Eurailtest and testing laboratory. SB, KTL, and consultants have sat down several times to discuss the entire test objective, and have been discussing it for about ten days on a business trip to visit the test laboratory. When there was a change in schedule or requirement as the test progressed, the decision was made immediately after consultation with the KTL. After discussing the contents discussed and filtered by SB and KTL, the consultant contacted SNCF-AEF and Eurailtest to adjust the schedule locally, and informed KTL and SB of any changes and exchanged information and decisions. In particular, the role of consultants to continuously communicate with European institutions played a very important role in the situation where KTLs were not able to travel easily to and from European laboratories. The situation in Korea and the reaction or situation in the European Testing Laboratory were as quick and as continuous as possible, helping them to make a decision.

At this time, the client was KTL. After SB and KTL had arranged their opinions through consultation, KTL communicated with the consultant with this content. This was changed to a structure in which the consultant contacted the testing laboratory. In the first test, there was an intermediate institution called Eurailtest before the laboratory, so it was indirectly contacted through this institution. However, in the second test, it was a structure that immediately contacted the technicians of the laboratory without an intermediate institution. In the second test, KTL signed a direct contract with DB Systemtechnik the test.

Comparing the communication systems of the two tests, it was much easier for practitioners to communicate with DB Systemtechnik and conduct the test. Interviews showed how the agency's communication system had affected the test process, most notably in the case of the second German test, an intermediary named Eurailtest, such as when it was tested with the first SNCF-AEF, caused inconvenience for practitioners in the entire communication system. From an internal perspective, there may be a middleman like Eurailtest, so it may be better to take administrative responsibilities, but direct communication with outsiders, especially practitioners, was much more effective, reducing time and effort. For example, a project manager in charge of contacting KTL once stopped working due to maternity leave, and as such, the middleman had an issue and delayed the lead time when dealing with it. Because the people in Eurailtest were not technicians, no matter how technical the KTL used to explain and how the arbitrator communicated with the laboratory, it was difficult to convey the KTL's position as it wanted. The same content was repeated twice, creating concerns about time delays and content changes. Therefore, even if there was a person in charge of the Eurailtest in the middle, it was necessary to meet with the technicians of the laboratory and exchange explanations in person. In comparison, the test with DB Systemtechnik was rather efficient and easy in this communication system.

As in tests in France, engineers and technicians were able to connect directly without an intermediary called Eurailtest, and since this communication and knowledge transfer structure was ultimately the model that KTL wanted, it can be assessed that the tests were more relevant to the purpose.

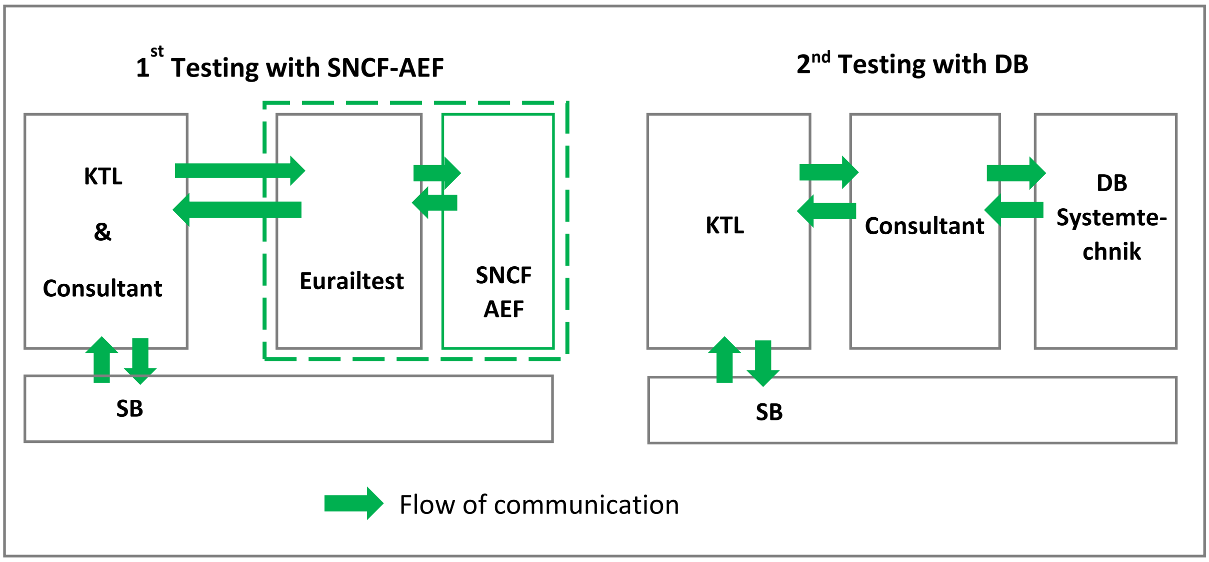

Figure 18 Difference in the communication system between the two technical certification test process

In conclusion, the summary on how communication took place during the two tests and how the communication structure changed during the two tests, as can be seen in Figure 18. First of all, the hassle that both KTL and consultants communicated between Korea and foreign institutions in the first test reduced dual communication by using a structure that focuses on communication with domestic institutions and consultants with laboratories in the second test. Also, while the technical test, SB and the testing agency DB Systemtechnik were in the same position as the 2018 test, there was a change in the position and relationship between the KTL and the consultant, which can be said to show a more systematic structure than the first test process. This change in structure or network phase was for more efficient testing and communication.

Above all, by strengthening KTL's position as the organisation representing SB and strengthening its role as a consultant, it can be seen as enabling consultants to deal with overseas testing laboratories with greater responsibility and confidence. In the first test, the consultant’s communication links were to four different institutions: SB, KTL, Eurailtest and SNCF-AEF. Although SB and KTL discussed the test process and requirements together first, and then KTL passed the result of the discussion to the consultant to reduce the communication channel with SB, in many instances, the consultant was required to contact SB to check and confirm the details of the test personally. Additionally, the consultant needed to communicate with Eurailtest on administrative tasks, with SNCF-AEF for checking the testing schedules, and with engineers when an issue occurred during the test process. From the consultant’s point of view, it would have seemed like a time-consuming process.

During the second test, the consultants' role was expanded. It became more independent, as a network structure has been established that focuses more on communication with overseas testing laboratories, enabling him to demonstrate his capabilities fully. In the second test, some changes were made. First, the testing centre was changed from SNCF-AEF in 2018 to DB Systemtechnik in 2019. This was because DB Systemtechnik’s test fee was cheaper than SNCF-AEF’s due to delays in communication with the previous institution. Second, in response to the inefficient communication system in the first test, a different approach was applied to the second test due to the complex communication channels. KTL, following communication with SB, filtered the result of the correspondence and then delivered it to the consultant. Therefore, the consultant was not required to contact SB and instead was able to focus on communication with DB Systemtechnik. KTL took full charge of communication with SB, and the consultant took full charge of communication with DB Systemtechnik. This made the test procedure much easier to understand and process. Because of this more apparent communication system, KTL and the consultant were able to concentrate on their respective roles and were able to manage their time and effort efficiently.

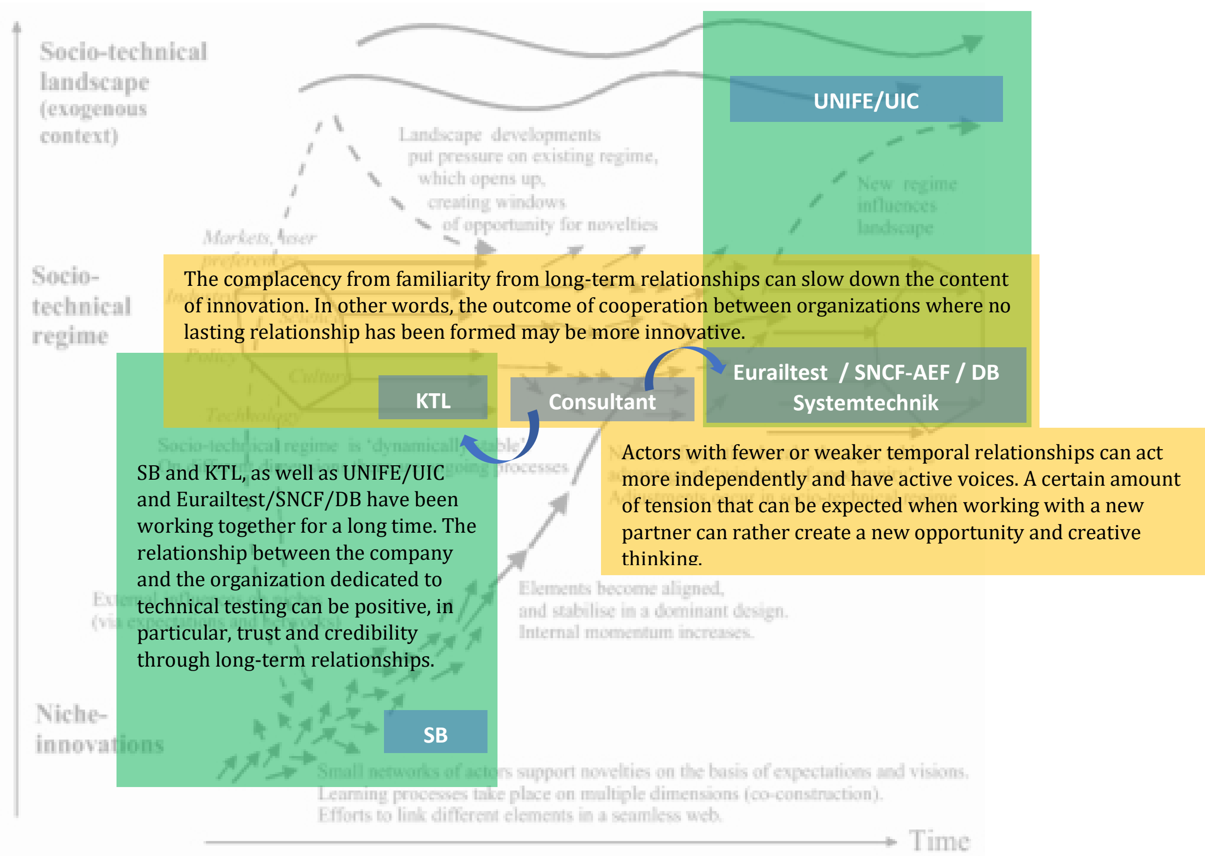

Figure 19 Relationship according to the duration of collaboration

It is possible to analyse that a new recognition of the importance of the consultant's role in solving problems experienced in 2018, the testing lab's schedule disruptions have affected it, as shown in Figure *19*.

To solve the problem more actively with a louder voice, without being hindered by domestic institutions' visits or schedules, it is recognised that it is crucial to focus on dealing with foreign institutions by organising unnecessary communication channels. With these changes, the KTL was able to gather opinions from participants in Korea to more clearly perform its role as an intermediate agency representing the positions of Korean institutions. Also, establishing and testing a communication system to be used in domestic technology certification tests linking foreign institutions as long as it ultimately seeks to obtain them through tests. Also, the arrangement of communication channels is a developmental method for testing laboratories as well. It is an obvious solution even for laboratories that geographically close consultants organised client opinions and thoughts.

6.3 KTL's Activities for Building-up Innovation Process: Information and Knowledge Exchange

Along with communication, exchanging and sharing information and technical knowledge for testing is essential for the research. Mowery, Oxley et al. (1996) view knowledge sharing as an exchange of information over the network and emphasises the importance of complementary assets in innovative areas. For example, suppose a company is strong in a particular technology, and another company is able to produce a product using that technology. In that case, the two companies will work together to enhance public capabilities. In addition, according to Powell and Grodal (2005), knowledge sharing and exchange occurs when existing information in the network is recombined by new methods. This is because it affects how KTL can accept and learn each agency's information and determine whether it can use it in the future by adding new methods. First of all, knowledge can be divided mainly into implicit knowledge and formal knowledge (Nonaka 1994). Implicit knowledge is acquired through experience but refers to unformatted knowledge or information, such as documents, such as a technician's skills in years of training. Moreover, formal knowledge, like documents, books, blueprints, and technical specifications, refers to knowledge or information that multiple people can share by exchanging, for example, product assembly manuals. Since the case used in this study is a technical certification test, the knowledge here can be seen as many things related to technology.

The knowledge exchanged between the KTL and test labs varied with the stage. In the test preparation process, primary documents such as technical forms and contracts were needed for various contracts and preparation, mainly formal knowledge exchange. For doing the test, SB and KTL had to prepare many things beforehand as follows; checking the test brake pads to be fitted to the SNCF-AEF test machine specifications, setting the exact purpose of the test, confirming the types of trains to mount the test brake pads, checking the content of the brake pads, and so on. KTL was responsible for coordinating the schedule with the testing agency by consulting with the consultant while informing and confirming the upper body of these preparations so that they could be prepared accurately. Following the KTL's guide, SB performed the necessary preparation work, and the consultant communicated the details discussed with them to the laboratory to support the preparation work for the test. Following the conclusion of the contract through Eurailtest, SNCF-AEF also conducted test preparation work to provide the best solution in the test process to support the acquisition of European certification of Korean corporate products based on accurate information.

During the test process, the laboratory conducted the test in accordance with a guideline called UIC leaflet, and KTL also understood each test process and method based on this. The deficiencies could have been filled with explanations by technicians during the trial, which can be seen as an implicit exchange of knowledge. The UIC first operates the certification program to comprehensively describe the overall flow of information and technical knowledge during the test process. Both SNCF-AEF and DB Systemtechnik have experts designated by UIC who have participated in creating these UIC certification programs.

Another main reason for KTL's decision to conduct overseas technical certification tests for SB's technology was its lack of understanding of overseas certification schemes. For example, as KTL tried to document the content recorded in the UIC certification preparation manual, they realised that there were ambiguities and limitations in interpreting it (which could be related to linguistic differences). These were things that could only be learned and solved through communication with engineers during the test process. However, when such problems were discovered, there was no way to solve them in Korea, so it was essential to be able to communicate with the experts stationed at the overseas laboratories. Although there were no pre-supplied documents or guidebooks to the laboratory, the entire process was carried out based on the standard of 'UIC leaflet', and engineers at the laboratory were able to correct any differences in interpretation within the leaflet. Through these tasks, KTL understood and learned the problematic parts as they continued to be checked and proceeded.

Table 27 Information and knowledge exchange during the test process

Testing Process	Explicit Knowledge	Tacit Knowledge
Pre-test	The list of specifications, contract form, the list of requirements, Components	Methods and systems of other agencies that can be observed during the test

	analysis of brake pads, timetable, test procedure, risk management plan	preparation process, communication systems
During the test	UIC leaflet (for testing process guidance), test procedure confirmation by a witness	Explanations and knowledge-how obtained from exchanges with technicians and engineers during the test
Post-test	Raw-data, test-report	

The knowledge exchanged in the two tests is classified as shown in Table 27, depending on the type. In the test preparation and contract process, various information, schedules, contracts, test procedures, and risk management plans provided by the testing agency are included in the test preparation process, including testing laboratories, test products that meet the UIC certification standards, and components analysis tables of the brake pads. During the test, the UIC leaflet, which serves as a guide to understanding the contents of the entire test process, and the test procedure for verifying the suitability of the test process through the witness were used as knowledge of express. After the test, there were raw data and test reports provided by the laboratory. On the other hand, tacit knowledge exchange was found mainly during the preparation process and testing. In the preparation process, the methods and work systems of the other party, communication skills, and systems observed or experienced while having meetings and exchanges with each other to plan the test, and the technical explanations and know-how they exchanged with the technicians during the test. Here, even if the knowledge intended to be obtained from explicit knowledge is a post-test result, as mentioned earlier, the most influential thing in light of the ultimate purpose of the tests held by SB and KTL was the exchange of tacit knowledge during the test.

Among the methods that Kinsella (2002) proposed to manage knowledge, KTL can use the methods that correspond to 'networking with matters from their experiences', 'communities of practice and special interest groups' and 'training events to share knowledge' throughout the technical process. In general, organisations strive to find many ways to increase the proportion of knowledge related to knowledge management. They also find ways to convert tacit knowledge into explicit knowledge and make it as explicit knowledge as much as possible and find ways to identify those who possess fundamental tacit knowledge and to continue to employ those people. The problem is the difficulty of making tacit knowledge into explicit knowledge. It is easy to format the speed and amount of accumulated experience and know-how in real-time and complex to visually articulate them to any given form.

However, tacit knowledge, which has been emphasised by Polanyi (1966), has a much broader domain than explicit knowledge and has many positive aspects. For example, from an organisational point of view, effective work styles or experiences can become tactful, and many members learn it, which can increase the organisation's light-jack power. Nonaka and Takeuchi (1995) explained that having similar types of assets and explicit knowledge would result in an organisation with more tacit knowledge, which would make it difficult for other organisations to identify the source of their competitiveness no matter how much they study and benchmark it. In addition, from a personal perspective, the more competitive the tacit knowledge is, the higher the value of oneself, and the organisation actively invests and supports these people. When such knowledge and skills accumulate at the organisational level, they can create preoccupation effects, and companies that are able to utilise this information can develop new knowledge. Also, they can introduce continuous innovation (Malerba 2004). In this regard, KTL has made many efforts to acquire knowledge through operational experience in the tests.

Tests of case studies have shown that knowledge plays a vital role in KTL's efforts to identify explicit knowledge (UIC leaflet analysis) that was unclear through its testing experience with overseas testing agencies to create and verify an effective communication system and to use it in the future. This has influenced knowledge exchange to be much more dynamic and harmonious. In general, when we describe knowledge exchange, we tend to think first that tacit knowledge is difficult to give and take compared to knowledge. However, what was confirmed during the technical certification test process was that the exchange of tacit knowledge was a very effective way to support explicit knowledge exchange. For example, before the test, KTL had read and checked the contents of the UIC leaflet to understand the content and process of the test. At this time, the KTL found that some parts were interpreted and not understood, which could be caused by organisational or linguistic differences when various certification test systems were learned from different perspectives. Related to this, what could have been found in both trials was not simply to identify and share the exchange of knowledge defined in several studies, but rather to overcome and resolve the ambiguity or difficulties that may arise from knowledge of explicit through the process of exchange of knowledge of the approach.

Thus, the KTL needed to resolve and confirm questions about these things during the test process, which could be solved by communicating directly with the lab technicians, listening to their explanations and learning. This can also be explained by the process of knowledge creation mentioned by Nonaka (1994). He said that the knowledge of tacit can be learned and transformed into the knowledge of socialisation, externalisation, combination, and internalisation. In conjunction with this, it can be understood that if the technicians in the laboratory unravel their tacit knowledge into a kind of explicit knowledge through communication in the field using dialogue, the KTL collects, combines and learns it through internalisation. In conjunction with the theory of mutual innovation outlined in MacKinnon, Cumbers et al. (2002), it can be understood that knowledge of tacit is essential, that knowledge creation is inherent in all activities rooted in social relationships, that social and organisational innovation is important, and that the ability to accept and learn knowledge is the basis of innovation. In particular, the tacit knowledge is relevant to the location and time of the interaction, namely specific and practical situations (Nonaka 1994). It has been confirmed that communication at each laboratory and each stage of the test process provides the desired information or technical knowledge and provides an opportunity to create and develop relationships through the sharing of the knowledge in other organisations.

Besides, there have been many studies on how easily explicit knowledge is delivered compared to implicit knowledge, and there have been studies that have shown that communication is more important when the knowledge to be conveyed is implicit. According to Asheim and Gertler (2009), commonalities based on experience, collaboration or informal interaction, and communication facilitated by a shared institutional environment help promote the delivery of tacit knowledge among people on the network. Furthermore, some studies show that the longer a partnership is, the more knowledge exchange varies depending on the length of time in a relationship, such as learning to fill the insufficient experience and reduce the side effects of knowledge that increase complexity by developing a common language and sharing mental models among partners (Simonin 1999). So, on the contrary, can the impact of learning (experience) on short-lived relationships be effective in reducing the side effects of knowledge that have become complicated over extended periods? Alternatively, whether learning and experience positively impact technology knowledge exchange, regardless of changes in the duration or target of the partnership. Thinking about these questions makes it possible to ascertain the importance of learning in knowledge exchange.

KTL also has a lot of technical test experience connected with foreign institutions even before SB's technical certification test support. Previously, tests conducted with overseas institutions were conducted to verify that overseas technologies were manufactured and available to Korean standards when they wanted to be used domestically, based on the Korean Railway Operation Safety Act, called the Type Approval System. It was the task of taking a business trip to the place where the applicant is and using the facilities there to test and certify when the relevant national institution entrusts the KTL with the test. In other words, it is a certification test for the advancement of foreign technology into Korea, just as Korean companies are undergoing European technology certification tests for use in Europe. In addition, the KTL had experience in conducting overseas agency connection tests, such as this study case SNCF-AEF and DB Systemtechnik, in conjunction with testing agencies in other countries. Based on these experiences, KTL showed that the duration associated with the communication system did not significantly affect the test process or results.

According to an interview with a KTL official, companies that have long known and worked with each other on the part of a commissioned laboratory will make efforts to make it easier on the technical side or minor issues related to the progress of the process. SB has long been involved in technology development, so it may be an example of an effort to reduce lead time. However, there may also be adverse effects that long-standing cooperation in the relationship can have. It should also be considered that the same actors' repeated correlation and cooperation can be expected to increase efficiency and reduce time and material consumption by reducing unnecessary processes through trust. At the same time, there is a possibility that there will be problems in terms of fairness and neutrality, or other opportunities to work with new partners will be missed. Suppose the organisations working together do not continue to make developmental efforts. In that case, the counterparts will find it difficult to acquire better technical information and knowledge, which may hinder the growth and development of the organisation. On the contrary, by forming a new relationship, the possibility of new knowledge and information exchange among organisations can be increased.

Looking at the two tests from the perspective of KTL's new network formation with the laboratory, as an organisation that commissioned the test, it had a process of investigating the laboratory to select one or two years before the test. In the case of SNCF-AEF and its test, consultants visited SNCF-AEF and Eurailtest in person, and KTL also visited SNCF-AEF in advance to determine the feasibility of the test; explain the R&D that KTL is conducting, and mention future test plans. Similarly, DB Systemtechnik labs have been continuously working with test workers for about a year or so to visit them in person and share opinions on the possibility of testing. Thus, both laboratories had previously held some testing consultation with SNCF-AEF, and first began testing with SNCF-AEF. As mentioned in the organisational culture or system, DB Systemtechnik tended to be a little conservative compared to SNCF-AEF, so communication was not accessible at first. When communication with the first connected people in charge began, it was not easy. However, KTL met a higher-level test operations manager at the DB Systemtechnik Laboratory, and since then, communication has been more accessible, and many problems have been solved. To sum up, even previously unrelated laboratories had some confirmation periods, and of course, the entry process was more demanding than other long-standing institutions. However, it was not noticeably challenging to proceed. KTL had questions about the uncertainty that came because they worked together for the first time, but after the test, KTL and test centres gradually became aware of each other's availability. When we asked for something, they could predict the results, so trust built up, and there were no difficulties afterwards. Moreover, in the second test, it was easier because, during the trial consultation, the consignee (DB Systemtechnik) showed an active attitude of predicting and approaching the trustee's demands (KTL) first.

Of course, this may be because KTLs and laboratories interacted with some level of communication systems. However, many scholars have generally studied the relationship between duration and efficiency as a positive proportion rather than a negative one. From a different point of view, the KTL's technical certification test process has confirmed the possibility that different opinions and results can be obtained. We can find supportive activities as shown in
Figure *19* and Figure 20.

6.4 KTL's Activities for Building-up Innovation Process: Problem-solving during the Testing

Most of the soluble problems in conducting certification tests in conjunction with overseas institutions are caused mainly by linguistic, cultural, geographical and organisational cultural differences. Among them, it was easy to see that the effects of geographical differences on communication had a negative impact on the risk that the agency had to bear. KTL, which is also in charge of domestic technical tests, said that compared to the experience of domestic tests, there are specific difficulties in testing through overseas labs.

When comparing the domestic and overseas tests, the most significant difference is lead time. In order to conduct a test efficiently and adequately, it is necessary to prepare and cope with the test. All the time taken to conduct the test through consultation, procedure, consultation, and the contract is planned and confirmed through prior consultation, verification of testing facilities and equipment, and testing is carried out. Sometimes for unexpected reasons, time is needed to reduce the risk as much as possible. Compared to domestic tests, overseas tests often have little time to check for technical aspects, and therefore, they are carried out entirely on the technical capabilities of the other agencies. In this case, procedures such as preliminary investigations are required. If a product to be tested is sent to an overseas institution, and there is a technical problem with the test equipment or interface, the time requirement arises accordingly. There is a difference in the time and method of coping with risks compared to domestic institutional tests. The difference is whether or not a technical issue can be directly addressed or not. Usually, it is necessary to prepare and verify all the technical issues from A to Z in advance and start the test after seeing the possibility. However, in domestic cases, direct handling of technical issues can be done as soon as possible. However, running this part is both a difference and a challenge, as overseas testing takes a long time to respond to and cope with issues.

In this regard, we could find a case during the technical test. For SB's brake pads testing with SNCF, a disc was prepared in advance of Korean participants' arrival in France. However, it should be remade because the material on the disc did not meet the specifications of the laboratory. So, people needed to wait until the new disc was prepared again. Therefore, KTL experienced a situation in which lead time was more than expected. This part was also confirmed in interviews with KTL and overseas consultants. When asked whether the progress was made according to the agreed schedule, even though the upper body had prepared the brake pads, it had been a problem that SNCF-AEF had delayed producing and preparing the discs to be tested with the pad on. The reason was that SNCF-AEF outsourced disk production, which was delayed due to various circumstances. In Korea, SB and KTL came on a business trip to attend the test, but Eurailtest and SNCF-AEF failed to give prior notice of the disruptions. The business trip in Korea was challenging to control, and it was a very challenging situation because this changed schedule was reported when people had already arrived in France. This was not a situation to be tested because the ordered disc did not arrive at the laboratory, and the brake pads did not bed for the test. However, KTL and SB needed to understand the situation that happened. Because, as shown in interviews with KTL officials, there are always some unexpected variables and risks, so it is dangerous to conclude that it is either fault. Because these situations can occur frequently, it is common to give plenty of time before and after the scheduled test date, which is called buffering.

In addition, it is common for European companies to request certification tests and request only the results without having to refer to them. However, since the first test with SNCF-AEF was a general test aimed at technology development, SB and KTL wanted to attend the test and therefore had to plan a business trip, which was cumbersome for the laboratory. Tests were usually conducted over a couple of weeks, and SB and KTL were only observed for a certain period before and after the test. It was not easy to observe all the tests unless the person who wanted to attend stayed on the business trip for a long time. Also, it was difficult in practice to ensure that the test was carried out and completed on a precise schedule since the test process and duration often change depending on the circumstances that occur before the test is conducted. Therefore, even if it did not go according to schedule, it was too much in the final period because of someone's fault. The above examples confirm that responding to these risks clearly indicates difficulties and other cultural or linguistic issues.

On the other hand, difficulties could also be found in organisational or cultural factors of the organisation. Since the early 1980s, invisible elements such as unique values, ways of thinking, and patterns of behaviour within a company have been widely introduced to the public under the concept of organisational culture, and have become aware that these factors are significant to the success or failure of a company (Kim. I. 2016). The culture of this organisation must be understood in order to understand people of the organisation's behaviour because these are the fundamental beliefs that a particular group has devised, discovered and developed in the course of solving the problem of adapting to the external environment and integrating the interior of the organisation. Also, this is something that the members of the organisation have long recognised as valid and taken for granted among them without any doubt. The new members are taught in the right way to solve the internal and external problems of the organisation. (Edgar 1992).

In general, there are many hierarchical organisational cultures found in the East. This emphasizes the efficiency and uniformity of the organisation's interior, which values organisational stability and is widely observed in organisations led by conservative leaders compared to other types. On the other hand, it is easy to find organisations in the West that tend to rational culture to emphasise productivity, performance, the achievement of purpose, etc. Organisational culture has a broad impact on all the management processes of an organisation. That is, since the organisational culture plays a role in the process of daily business processes, interchanges, especially decision-making processes, a correct understanding of organisational culture increases the likelihood of efficient management or management success. Therefore, in the two test processes of the case study, KTL and consultants confirmed that they had put a lot of effort and attention into communicating and exchanging knowledge with officials from each laboratory and related agencies.

Table 28 Organisational Culture of Overseas Institutions Related to Testing

Overseas Institutions	Organisational culture
Eurailtest	Valued individual responsibilities and roles, casual but somewhat individualistic.
SNCF-AEF	Emphasis on individual responsibilities and roles, no intervention other than one's duties.
DB Systemtechnik	The very closed organisational environment in the beginning, bureaucratic.

Table 28 summarises their organisational culture discovered during the process of communication and knowledge exchange with the three institutions involved in the test. First of all, Eurailtest values individual responsibilities and roles. The method of dealing with the counterpart was less bureaucratic and casual than with other agencies, but more or less individualistic organisational tendencies. As mentioned earlier, when someone in charge of KTL's affairs changed, it took a while for someone else to get the job and contact him or her. The new person who came to replace him or her was not able to get the job clearly from the previous manager, resulting in much time delay in communication. In the case of SCNF-AEF, it was generally confirmed that individual responsibilities were essential to each other when working. In the project that was carried out together, SCNF-AEF was in charge of administrative tasks such as contracts, assignment of duties, and other technical tasks, such as writing tests and reports. However, from the KTL's point of view, Eurailtest and SCNF-AEF were unable to answer questions because they were not each other's own business.

DB Systemtechnik was a little different. KTL was impressed that regular communication with DB Systemtechnik staff was difficult before the project. However, after accidentally meeting with a high-ranking official at a technology fair, the work progressed rapidly, which made me feel disturbing that it was somewhat bureaucratic. After this connection, the technical pride of the person in charge was so strong that many technical questions could be solved, and from the KTL's point of view, this was very helpful. Although there is some rigidity in bureaucratic organisational cultures when working together, the firm organisational control enabled its members to experience accurate, prompt and specific work processes in many ways. The organisational characteristics of each of these institutions could be identified several times during the tests, and such diverse organisational cultures were experienced several times during the test process. The ability to cope with the problems was enhanced by the efforts to understand and resolve the organisational culture of the institutions.

KTL and overseas test labs have their positions and different capabilities and have their limitations accordingly. In particular, in the case of testing laboratories, there may always be variables in the management of machines, and there are problems that need to be adjusted while testing. In this case, it is common to stop all tests and solve problems before proceeding again. In this regard, a similar case was found in interviews with overseas consultants during the second test.

In the case of SB and KTL, they also have test labs and test facilities. Although it is simply a domestic test, the reason for testing at European laboratories is that even though the UIC standards and specifications available for machines owned by SB are not compatible, for developed markets, even if the testing protocol is internationally defined, they also want to learn from the specialised processes during the test and the knowledge held by the agency's engineers. Since KTL and SB had a significant purpose of learning invisible hidden knowledge, hidden systems and operating systems through test attendance, the possibility of some change had to be kept in mind.

In the case of the second test, a problem occurred during the test on the dynamometer (brake pads test machine) prepared by DB Systemtechnik for the test, resulting in the suspension of all tests and reschedule. In order to prepare for a test again, the laboratory has to bear the loss caused by not conducting the test for that period, so it is common to test the products scheduled for later testing in a different order first. In this case, it is easy to change or adjust the order for European products, and in the case of KTL and SB, the situation was complicated because they wanted to attend the test. Whenever a test schedule was set, SB, KTL, and consultants visited the local testing laboratory to observe. However, when SB and KTL faced an unexpected situation, they felt troubled, but they had to understand that it was a situation they needed to understand. For these reasons, it was inconclusive that anyone was responsible for the changes during the test. At this time, the role of overseas consultants was confirmed.

The consultant's main task was coordinating and communicating the test schedule by communicating with local agencies and laboratories. It was challenging to solve the problem if the above sudden situation caused a setback in the test schedule, even though thoroughly prepared. In particular, the entire meeting was held because the damage seen by the organisations that came to Korea for the long-distance test was not minor. At the end of the meeting, it was also the duty of overseas consultants to help bring about the results of the compensation in other ways. First of all, it was the consultant's role to examine the positions of all the officials and stabilise the situation and atmosphere so that subsequent communication can be natural and understand each other as much as possible. They have intermediated to understand each other's conflicting elements that result from their organisational and cultural differences. Since it could not be certified without going through the test lab, efforts were made not to touch the test lab as much as possible. This was because, somehow, SB and KTL were in a position to get help. They tried to understand each other's differences in the working system. As a result, SB and KTL's positions were also accepted in various areas, which led to compensation for failing to meet the test schedule as planned.

First of all, available reports are provided regardless of whether they are present or not, so there are usually many restrictions if they want to attend. There is a reason why other companies usually do not do that. When they observe, engineers have to keep going around and explaining. Sometimes they need an interpreter. Where there are important facilities, they can be restricted even if they do so. Costs are incurred depending on the number of visitors or the duration of the visit. In many ways lowered the limit so that it could be considered to facilitate the visit. Additionally, test reports are generally given after the test, which does not include raw data. However, it was a very profitable situation for SB and KTL to receive this. Thus, when asked for this at first, the lab was reluctant, but raw data could be obtained as part of the compensation for changes in schedule. The reason why original data are important is that there are wet and dry tests for brake pad tests, which assume snow or rain conditions, and dry tests are tests under normal conditions, and these two tests are conducted separately. With raw data on these tests, you can understand the test situation in more detail. In the end, the raw data in each process was received without attending the test. Also, there is a camera filming of lacerations during testing, which is usually an extra charge. However, as part of the compensation, it was offered at no additional cost. The interpretable reason for this being more profitable is that much of the objectives of SB and KTL were in technology development and technology acquisition from the outset.

Besides, another example could be experienced in the differences between organisations. In the case of DB Systemtechnik, it was often too late to receive the final report from the user's point of view. Under the contract, the report came out within a month or two after the test, but it was tested in September and received the report the following year (over the year). Although this was the case, the KTL took a position to understand and accept each other's situation when it saw the entire process of attending and testing. When the test results can be used in Korea only when the test results can be used by the German laboratory, the results could be continuously checked during the test process. Therefore, KTL and SB were not impatient to receive test result reports, so it was understandable even if the test report came out late.

Overall, DB Systemtechnik did a lot of the test-related processes, and SNCF showed a tendency to place a little more limits on security if compared in this respect. In the case of France, it was observed that the engineers at the laboratory made progress smoothly when they had to contact the engineers to proceed with the test process after being connected to the Eurailtest. In SNCF tests, it felt softer and more manageable from the first contact, but there were also cases where the work of administrative and technical practitioners did not go smoothly with each other. This was judged to be a process to be taken, mainly because it goes through intermediate institutions. DB Systemtechnik's case, as mentioned earlier, was thought to have been a little conservative and bureaucratic. Because the engineer had to solve the sales and technical aspects directly, I felt that KTL was a little conservative when contacting DB Systemtechnik. When inquiring about a contract or requesting an answer, the response was rather insignificant. However, things began to go a little easier in England when I met with a consultant and communicated with the senior director of DB Systemtechnik. Attitudes have changed since the senior director began the process in direct connection with the laboratory's technicians. Since high-ranking officials directly intervened, other officials have responded more sincerely to the KTL's contacts and demands, strengthening the idea that the organisation is conservative. However, once the first threshold was crossed, communication was accessible and transparent. It can be described as shown in Figure 20.

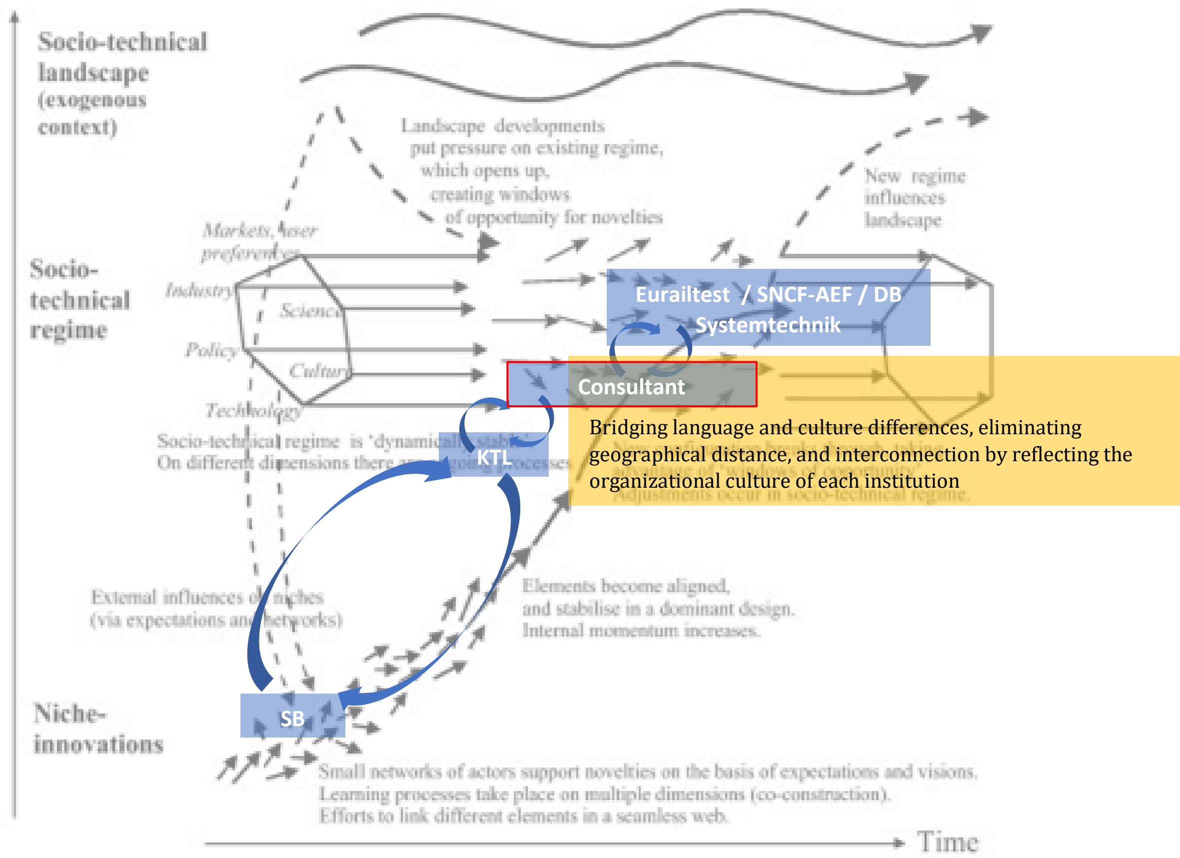

Figure 20 KTL's ideal communication structure through the test process

What can be reaffirmed through the experience of these various cases was the importance of learning and understanding the organisational and cultural characteristics of linguistic, geographical and cooperative institutions, and communicating and exchanging knowledge using this understanding when problems arose. It was the primary and most important way to solve the expected problem, and it could even lead to unexpected positive results.

6.5 Evaluation of the test process

To summarise the test results, we could confirm the following facts about the two tests' results. The technical certification test can be divided into two types: the general test and the certification test. The general test is aimed at obtaining the certification so that it can be used directly when the performance of the development product is desired in the middle of the research and development. The test with SNCF-AEF was a general test to verify the development product's performance in the intermediate stage. DB Systemtechnik was a certification test, which resulted in unsatisfactory results. If the technical standards that can be certified through the test are satisfied, the application for certification can be made. However, because the test results fell short of UIC standards, it was only a test report from the perspective of KTL and SB and, therefore, was not actually used.

However, these two tests' effects showed different aspects when it comes to testing networks and communication and knowledge exchange. First of all, the two test processes presented as examples were using a technology cooperation network. Such a technology cooperation network can broaden the resource base of participating companies by enabling partner institutions to take advantage of the formal and implicit technical knowledge they already possess, which can improve the performance of innovation. The network connected to these activities is critical to the success of the innovation, given that the technology collaboration activities increase participants' accessibility to crucial information and that innovation is a knowledge-intensive activity. Looking at the organisational and technical knowledge diversity and networks in which each of the relevant agencies identified in the MLP framework have connected and cooperated made it possible to confirm the importance of the network. In addition, organisations must understand the knowledge acquired and generated externally (Nicholls-Nixon 1993) and effectively apply the knowledge to increase the organisation's efficiency and reduce costs (Davenport and Klahr 1998). In this respect, even though the tested product did not receive technical certification, it achieved its purpose because it achieved results from knowledge exchange. SB obtained information on how much its technology has reached and its improvements to enter the European market. KTL was able to establish and test the communication and knowledge exchange models available for cooperation with institutions during overseas testing that they wanted. They had the positive result that the used model was effectively worked during most of the testing process.

In terms of cultural perspective, an essential point in different organisational collaboration networks is to deal with different national and organisational cultures. The cultural differences that could have been experienced in the two tests in this study were primarily those of different Eastern and Western cultures. If KTL had a hierarchical organisational structure characteristic of Oriental organisations, Eurailtest, SNCF, and DB showed a horizontal and rational organisational culture of Western organisations. Clear and transparent procedures and communication were shown in those three organisations. As discussed in Chapter 6, processes in which decisions or communication incorporated the whole were relatively time-consuming, as Eurailtest, SNCF, and DB valued individual roles and responsibilities accordingly. However, the changes in communication or progress due to the presence or absence of long-term partnerships, which are often seen in Eastern organisational culture, were less observed. Although national cultural differences did not affect much, they often occurred, but this was enough to overcome by the consultant's middleman. He understood and acted appropriately on the two sides' organisational and national cultural differences. Judging from this study's results, the impact of cultural differences on cooperative networks conducted with a common purpose (technical test here) was relatively low.

6.6 Chapter Summary

When connecting this with the innovation process network, the establishment and management of collaborative networks with various actors is a very important factor, which can be led to the conclusion that there should be smooth communication and knowledge exchange between the collaborators. Since diversity is an essential part of many industries, effective management of these factors is also essential that many agencies keep in mind. In line with these ideas, this study focused on the technology testing and certification industry and examined the network and interaction of various actors.

Global network and knowledge exchange are also vital resources for innovative ideas (MacKinnon, Cumbers et al. 2002). Innovation has been based on interaction, knowledge exchange, and learning between organisations, such as entrepreneurs, public organisations, and research institutions. Through this case study, it has been confirmed that the culture of the organisations, along with the linguistic and geographical factors expected when collaborating with overseas institutions, play a critical role in collaboration over the networks. In the cases, by using the result of the face-to-face activities between the actors which were contentable, we can confirm that the exchange of tacit knowledge, face-to-face interaction is essential to exchange tacit knowledge (Davids and Frenken 2018). As many researchers have explained, tacit knowledge takes a role of complement to understand and verify explicit knowledge (Asheim, Grillitsch et al. 2016).

In this chapter, the researcher has used the MLP model to analyse a specific innovation system. The MLP has shown itself to help identify new characteristics of the innovation system surrounding technical certification in the Korean Rail industry. It is the first use of MLP in the railway technology certification context. The use of MLP makes it easier to understand the relationships and interactions of various actors. In particular, it is a practical framework for analysing networks and activities in the socio-technological regime level: a ruleset consisting of scientific knowledge, engineering practices, technology, product characteristics, procedures, and the combination of institutions and infrastructure that make up the aggregated nature of technology, as described by Kemp, Rip et al. (2001).

The author has identified some insights into the specific innovation system which confirm the current understanding of innovation. One of the insights is that the investment in an intermediary would help innovators navigate a complex eco-system in terms of communication and networks; this matches the general literature on innovation but has not been previously observed in the rail industry. Other insights are novel, for example, that long-term relationships may be detrimental to innovation, while short-term relationships can be beneficial by providing the appropriate tension and novelty for the innovation process. Also, the organisation's culture is essential for collaboration within a network, and implicit knowledge serves as a complement to understand and verify explicit knowledge.

7. Discussion and Conclusion

This chapter summarises the study on the communication and knowledge exchange networks in the technology certification testing industry of SMEs in Korea and also suggests possible research areas which could be continued in the future. As part of the innovation process and activity, this study is completed by considering the importance of network building and management in the technology certification testing industry, the importance of the interaction of various actors in knowledge exchange and communication within it, the importance of developing the technology certification industry, and what value and where more research and effort in this field is needed.

7.1 Summary of findings

This study aims to enhance our understanding of the importance of technology developments and transitions in the railway industry for enhancing competitiveness globally by focusing on how KTL collaborates with various actors and organisations. To do this, I observed the recent two testings of the Korean railway technology with overseas agencies, which KTL involved as a supervision institution. I focused on the actors of these testing processes in terms of their networks which was built up to conduct the testing, and communication and knowledge exchange systems and methods between them. For doing this, the communication and network system in the process of receiving a technology certification test for Korean SMEs' entry into Europe was studied through real test cases.

According to Beckman and Haunschild (2002), business relationships among homogeneous companies are less successful than those characterized by heterogeneity, and some have shown that diversity promotes creativity and makes group interactions more effective (Carlile 2002, Kash and Rycroft 2002, Sammarra and Biggiero 2008). This diversity of networks affects innovation, the result of interactions between different industries and business, social and technical networks (Hagedoorn 2002). In addition, the network is influenced by its innovation results by various factors, including organization and policy, government support, project complexity, language, and organizational culture (Barnes, Pashby et al. 2002). They studied this diversity by examining the participants’ network using the MLP framework to explain the relationships between various levels’ actors. By examining their activities and roles, the technical certification systems and flows were also studied. I found that these various actors are mainly located in the regime-level of MLP framework which contains the different dimensions of activities and relationships for the configuration of niche technologies. With diverse and dynamic relationships in the network of technology testing, regimes of industry, policy, technology, science and culture were intertwined and influenced the testing process. Sometimes these influences caused problems, but sometimes these influences created a solution.

This is also a study on how the technology certification testing process can be effectively carried out by operating these networks effectively, by focusing on communication and knowledge exchange systems through the experience with the organisations in France and Germany, which are the powerhouses of technology testing and certification industry. In the two testings, KTL built up and used different communication systems and eventually found the appropriate and effective communication system. By using a complementary communication system in the second test, KTL was able to exchange knowledge and information more efficiently with the actors involved in the test network. This was one of the aims of KTL. Therefore, it can be said that these testings were critical for KTL.

It can be considered that this study contributes to many aspects. The first is, it introduces practical examples (cases) of the innovation eco-system concerned with the overseas technical certification test process of SMEs. By studying recent tests as examples, the updated certification testing process was introduced. Moreover, by applying the MLP framework, which was established by Geels, the railway technology certification test process was clearly described the interaction between the relevant actors and networks and communication systems used by KTL. For the railway and the technology certification industry, this kind of research has so far not been conducted much.

In relation to theory and practice referring back to the key bodies of knowledge identified in the literature review earlier, the data shows that KTL established and tested the communication and knowledge exchange models available for cooperation with institutions during overseas testing. They had the positive result that the used model effectively worked during most of the testing process. The consultant's involvement in resolving problems and issues also showed positive effects for building better communication and processing smother testing. We can trust this data based on the necessity of various resources from outside of organisations. This adds examples to the literature of Malerba (2004) and Iacono, Martinez et al. (2012), who emphasised that the concept of knowledge exchange between companies is tightly linked to the innovation process, and innovation is made with this external variety of stimuli.

The finding also shows that the MLP is a valuable tool for understanding complex relationships between diverse actors in the testing process. The relevant actors identified in the MLP framework have connected and cooperated to confirm the importance of the network. As shown in figure 19, by using the MLP framework, the researcher could clearly understand various activities and relative actors during the whole collaboration procedure. This result confirms the literature of Geels (2011), who the MLP framework is an analytical and exploratory way to understand system innovation. This also supports Genus and Coles (2008)'s statements that the MLP has led researchers to be interested in the interaction of various actors, the social-technical structure and the behavioural-harmonious rules in it.

In particular, the study is significant in that there were not many studies that tested the complementary communication system and confirmed its usefulness during two successive tests with the same product from the same company. On top of that, the study found the significance of KTL's role and support for overseas technology certification tests in terms of innovative technology development of SMEs in Korea. Furthermore, this study can provide room for research on KTL that can enhance its capabilities in the technology certification market and strengthen its competitiveness in the global market, as well as for the research on improving the certification test process.

7.2 Limitation and Future research directions

KTL's overseas standard certification support project is an activity for sustainable growth in technology development and innovation. Since the World Trade Organisation (WTO) regime was launched in 1995, the tariff sector which had been a significant barrier to trade has been drastically reduced. However, standards and conformity assessments are non-tariff technical barriers to trade, with safety, health and environmental protection being strengthened. Furthermore, the test and certification market continues to grow at a high rate in line with the improvement of income levels by county, the increase of technical regulations on quality, health and safety, and the increase of education globally. Although the railway-related certification system has different systems that reflect the characteristics of each county, its authority and responsibility in verifying suitability are clearly defined by stipulating roles and scope of work for manufacturers, certification inspection agencies, and users (KTL 2015). In particular, developed countries such as countries in the EU, Japan and the United States make an effort to enhance their competitiveness in the certification business by using various regulations. As a result, technology barriers of non-tariff trade have emerged as a new issue in trade between counties, and the demand for compulsory certification has increased with centring around developed countries.

In this environment of international trade, compared to the multinational enterprises which can secure the competitiveness in the international marketplace based on technical and financial strength, most MNEs who take almost half of the export trade of Korea have been struggled due to their lack of technical and information capabilities. Moreover, even technologies developed independently in Korea are found to be dependent on foreign institutions to evaluate their suitability, including testing and certification. This is because the test and certificate ability in Korea is lower than in other countries, which can cause problems in reliability, so it is requested to a well-known overseas institution from the beginning. Accordingly, the budget for overseas standard certification acquisition support projects has been increasing, which are to support 50 to 70 per cent of the expenses required to obtaining certification marks for overseas standards required by countries subject to export, so that exports can be facilitated by enhancing the reliability of products manufactured by SMEs abroad (MSS 2018). However, according to Park (2013), the research of the recognition path for the acquisition of overseas standard certification shows that more active efforts for information and knowledge sharing and provision by the government and relative institutions are needed. The result of the investigation of this issue reveals that SMEs are suffering from a lack of expertise and experience, so they are acquiring overseas certification through consulting firms which is causing additional costs. Although the government's supporting project received positive responses overall, many enterprises do not have access to it due to the lack of practical information. While the U.S. and EU take on 60% of the global market with global testing and certification agencies, Korea's share of 5.6% is also a bit of a problem. However, the Korea Institute of Technology and Standards (KATS) surveyed test and certification companies and found that the most inefficient certification system is the most problematic (Innothink 2016). Therefore, many experts in Korea argue that the national level's strategic support is needed, such as establishing an integrated certification system and minimising regulations. To do this, since 2016, the Ministry of Trade, Industry and Energy (MOTIE) has held a test and certification forum, which has been trying to find ways to secure competitiveness and make a leap into the global market (MOTIE 2016), and announced the enactment of the 'Compatibility Evaluation Management Act' and fostering human resources for testing and certification institutions to strengthen their capabilities (MOTIE 2020). Moreover, the project for the industrialisation of testing and certification services is to support the capacity building of domestic testing and certification institutions (KATS 2020).

As part of these government efforts, KTL, which has been selected as a project management institution to support an acquisition of overseas standard certification, has provided various overseas technical information, as well as services including an application for certification, acting as an agent for approval procedures, product testing, and also has supported part of the cost of obtaining certification. Notably, KTL established the overseas standard certification information centre, which integrates and manages overseas certification standards, and it enabled domestic companies' product development and quality control departments, various testing institutions and consulting institutions to easily obtain accurate certification procedures and the latest standards for export products (Kim 2017). Additionally, KTL has been making great efforts to play its role as a technology verification agency and expand its international network to improve technology through cooperation with foreign agencies and to support related companies.

The critical part of this overseas standard certification acquisition support project is to increase domestic technical tests' success through smooth communication and exchange with overseas testing laboratories and related agencies. There is no doubt that the company's technical skills should be based on the premise, but in many cases, even if they are backed up, there is not enough information. There is a lack of material and administrative support to begin testing, or there are many difficulties in effectively obtaining satisfactory results. Therefore, the role of KTL and the support of the government are significant. Based on this, studying KTL’s capability to build and manage networks, communication, and knowledge transfer systems would help companies struggling to develop technology and enter global markets. As Powell, White et al. (2005) explain, in the science-centric field, it is often the case that organisations that develop relationships with various other organisations and perform activities can play a central role in the industry network. In order to enhance the global competitiveness of testing and certification institutions to cope with the rapidly changing global environment, it is necessary to accumulate and utilise resources and strengthen the network with related institutions. Therefore, it is necessary to continue to strengthen mutual understanding and efforts for the development of inter-organisational communication and knowledge transfer systems and networks.

As railways have become a long-term and continuous development task for each country, various programs and systems related to railway research and innovation policies have been prepared and implemented in Europe as well. Implementation plans have also been in place for research in various areas, including the verification of the technology needed for future railway development, including research on competitiveness and technology, new strategies and economic aspects to implement them, maintenance and improvement of various infrastructure facilities, securing users and labour force, and responding to changes in railway assets (ERRAC 2013, ERRAC 2017). Thus, the testing and certification industry is an essential service industry for the manufacturing industry's sustainable growth and is a high value-added industry that is closely related to the export industry. Therefore, not only in the railway technology industry, but also in to grow the domestic manufacturing industry and to expand the export industry, both the testing and certification industry and the manufacturing industry must grow and respond together to the new environment of digital transformation (Lee and Mok 2019). With these efforts, it is also necessary to further studies for the establishment of a Korean-style model which can contribute to the strengthening of Korea’s technical certification capabilities, testing structures and systems, communication and knowledge exchange system and networks management, including acquiring information and technology of overseas institutions.

For the further research and work of this field, I hope my study will contribute to the following areas: First, for the Korean railway industry, my thesis presented and explained one of the international accreditation systems and testing processes. It can help broaden understanding of the railway industry. Also, it can confirm the importance of the development of an accreditation system. Second, for the MLP researchers, my work can be another research that examines the accreditation process by using MLP in the railway industry. Many researchers applying the MLP framework for their research, technological transition, system transition, and political system areas are commonly examined. For them, my thesis provides another exciting area to study. By examining uncommon areas, my thesis can show potential research areas and how MLP can explain them. Third, for the researcher interested in innovation networks, my thesis can provide an actual case study related to a not commonly studied area as one of the innovation networks. My thesis can show them that this kind of comparison study can be done: 1) basic setting and main participants are identical, 2) by changing some participants and communicating system, 3) which and how the results have been changed. It can provide real cases about how partial changes in the system can bring more effective networking and preferable results, which can be considered an innovation. It is because innovation is not only about the big, surprising things. It is also a collection of every little step and finds. Finally, my work can provide some insight into institutions or people related to the Korean railway development project for the practitioners interested in innovation networks. As mentioned in my thesis, the Korean government currently puts many efforts into and runs projects to develop the railway industry, technology, and accreditation system. In terms of networking and communicating with foreign organizations, by providing my case studies' results, they may have some idea to reduce unnecessary efforts and help find the more appropriate way to plan, design, and build communication systems as innovation networks.

Appendix. List of Interviewees and interview contents of in-depth interview

Table 29 The participants of the in-depth interview

Affiliation	Name	Position in the organization
KTL	San-Hyun, Kim	Chief Researcher of Railway Parts Evaluation Centre
KTL	Jin-Gyu, Park	Senior researcher of System and Energy Headquarters
KTL	Ji-Sung, Kang	Researcher of Railway Parts Evaluation Centre
Consultant	Jae-Hwan Park	Overseas consultant / Senior Lecturer of Middlesex University of London

Interview with Jaehwan Park, the connection and arbitrator of overseas institutions in technical testing in the case study:

- What role did KTL want for you?
  To talk about my role in this process, I think that we have to talk about the whole process first. To obtain an overseas technical certification for the SB, I had participated in two projects. Once was in 2018 through Eurailtest in France. At that time, I helped to conduct a technical certification test at a technical certification centre under the SNCF. The second is 2019, which is now. Currently, the German railway cooperation, DB Systemtechnik conducted the test. I can tell how when I was with SNCF-AEF and DB Systemtechnik, I had different cases and roles. The first time I worked with SNCF, KTL was an organisation that controlled, supported, and organised the whole process. Moreover, in the technical test, I communicated with SB directly through email, phone and meetings, then delivered discussed contents to the KTL. If there are any uncertainties or problems, both SB and I contacted KTL to organize them. I did not know whether the communication system was desirable or not at this time. In the case of working with DB Systemtechnik, KTL was in charge of communication with SB, and KTL informed me of what was done. I was in charge of communicating with the German test laboratory. It means, for me, there were two channels of communication in 2018. I had to contact SB and the test laboratory, then had to contact KTL. After that, KTL had to contact SB to make things clear and make further steps. Otherwise, working with DB Systemtechnik in 2019 was much easier to communicate and work with than in 2018, as the KTL took part in planning, deciding and managing almost everything of the process and informed me. Because I did not need to communicate with Korea, also I had much work with the testing laboratory during the process, this way of communicating was much better to work. Most of all, in 2018, there were so many adjustments and requirements from Korea (SB and KTL), which disturbed both the testing centre and me to focus on the work. To look at the test, the situation with France in 2018 was that SB commissioned one type of brake pad to test, and the UIC’s S1, S2 Drive

Test and Wet Test were conducted. In the test with Germany, two pads are tested. Although SB prepared three brake pads for testing, it is decided whether to test the second and third pads. So, the first pads were tested and following its result, and the second pads were tested. I will stop here.

- So, in this case, if the first test's result is terrible, you are not testing it again and testing another one?

  Yes, that is right. SB has a lot of kinds of brake pads and various results. The critical point is that it can be different between the result of the test of coefficient friction which they have and the result of the test of coefficient friction which did by the UIC certification centre. Also, it is hard to know what the test results of the Korean and the European certification authority would be. In the process, the case of Germany was more complicated than the case of France. However, the types of both tested brake pads were different.

- So does this mean that the 2019's process was easier to work on than the 2018's process?

  The way of working with French and German testing centres was a bit different. I will tell you later which was more convenient for me. The clear thing is that since I was a middleman, I needed to communicate with both Korean and European agencies. In terms of communication with Korea, I think that 2019's process was more comfortable for me and smoother in carrying out the whole process. Because the KTL and SB discussed and decided on all the needs and requirements which should be adjusted before and during the testing process while I communicated with the European agency. So, the requirements and main schedules were set up before I got in touch with KTL and SB to deliver the schedule of the European agency, and it made the process even better and efficient. SB is an institution that participates in government projects with government subsidies which are given by KTL as a developer, and KTL is responsible for commercializing the overall export of overseas railway parts. Therefore, these two have the same purpose of developing Korean railway technology but have a different positions. In between these two institutions and foreign testing agencies, my role is to adjust and support their collaborative work because the process of accreditation is always complicated. For instance, even if it was planned to start on 1st September, there were some complex cases where things would go as planned depending on the various situations at the local testing centre. It was my job to coordinate and help these things.

- I think there will be more businesses for domestic technologies to be certified overseas. Are there any particular concerns do you think following your experiences?

  As I learned from these two cases, the way France and Germany's work is different. France must go through a relay operator, and this is not easy. It is an entirely different system. Germany does it directly through DB Systemtechnik. So, I felt it was essential to understand the different systems and working styles of chosen overseas institutions. Even if it is trivial, such as planning a business trip, some difficulties come from different cultures. Also, I think it is vital to building a trust relationship with foreign institutions. How can people like me connecting in the middle to effectively meet both sides' benefits? How to maintain a trust relationship usual days can help future processes without any disadvantages. By doing this, when Korean companies want to ask for the test in the future, companies can get invisible help. The purpose of Korean companies to certify overseas testing and certification is to learn advanced foreign technologies as well as to obtain certification. Therefore, building a trust relationship is the most important to bring more benefits to our technology development.

- During this process, have there been external agencies that have influenced other directly related agencies? Are there occasions when external forces work?
  It is fair to say that these institutions were the only ones involved in the process. It is because the purpose is to obtain a UIC certification, so the UIC is in charge of the whole process. However, since SNCF-AEF and DB Systemtechnik are members of the UIC, it means that they need to follow the UIC's rules rather than UIC influence them.

Interview with KTL participants in the case study:

- Let me ask you about the SNCF-AEF test. During the communication process with each institution, was there anything unusual about each organisation? If there was, what was it? Unusualities include the characteristics of the institution, communication systems, ease of use, difficulty or difficulty, and differences found in the domestic test experience: The KTL also provides test support to domestic institutions, which were conducted with overseas institutions. When comparing the domestic and overseas tests, the most significant difference is lead time. In order to conduct a test efficiently and adequately, it is necessary to prepare and cope with the test. All the time taken to conduct the test through consultation, procedure, consultation, and the contract is planned and confirmed through prior consultation, verification of testing facilities and equipment, and testing is carried out. Moreover, sometimes for unexpected things, time is needed to reduce the risk as much as possible. Compared to domestic tests, overseas tests often have little time to check for technical aspects, and therefore, they are carried out entirely on the technical capabilities of the other agencies. In this case, procedures such as preliminary investigations are required. If a product to be tested is sent to an overseas institution, and there is a technical problem with the test equipment or interface, the time requirement arises accordingly. There is a difference in the time and method of coping with risks compared to domestic institutional tests. The difference is whether or not a technical issue can be directly addressed or not. Usually, it is necessary to prepare and verify all the technical issues from A to Z in advance and to start the test after seeing the possibility. However, in domestic cases, direct handling of technical issues can be done as soon as possible. However, running this section for overseas tests is both a difference and a challenge, as it takes longer to respond to and cope with issues. For example, when testing with SNCF-AEF, there was a test material called a disc to test the braking pad, which was not identified before going on a business trip, and then had to be remade because the material on the disc did not meet the specifications and materials required by the laboratory, resulting in an unexpectedly high lead time situation.

- What are the advantages and disadvantages of communication in the situation where Eurailtest is connected?
  From the perspective of practitioners, it was much easier to contact DB Systemtechnik. As in tests in France, engineers and technicians were able to connect directly without an intermediary called Eurailtest, and this method was much more convenient to communicate with. It may be better to have a middleman like Eurailtest from the inside. However, it was much more effective (from the point of view of the working person) to communicate directly to the outside world's accessibility, saving time and effort. The middleman thinks it was a factor that delayed lead time. Because the people in the Eurailtest were not engineers, no matter how technical terms we (KTL) used to explain and how the arbitrator communicated our position with the laboratory, it was difficult for us to deliver as we wanted. Therefore, even if there was a person in charge of the Eurailtest in the middle, it was necessary to meet with the technicians of the laboratory and exchange explanations in person. As I will tell you later, tests with DB Systemtechnik showed some problems (difficulties) in terms of language, although they were more efficient and easy in these communication systems.
- How did the communication with the upper body brakes and consultants take place?
  We consulted with Professor Park Jaehwan on the details of the filtering and discussed with the upper body brake and KTL to contact the laboratory. With the KTL not coming and going quickly, the role of a consultant to keep communicating with European institutions was significant and helpful. The feedback on the situation in Korea and the reaction or situation of the European Testing Laboratory was as quick and continuous as possible, which helped us to make a decision.
- What were the results regarding certification?
  The test can be divided into two types: general test and certification test. The general test is a test aimed at obtaining certification so that it can be used directly when the performance of a development product is desired in the middle of research and development. The test with SNCF-AEF was a general test to verify the performance of the development product in the intermediate stage, and the test with DB Systemtechnik was a certification test. However, the result was that it did not achieve enough results to satisfy the performance. Suppose the entry conditions are satisfied through the test. In that case, a certification can be applied for, and it is probably for

the promotion of the testing laboratory (perhaps the test is being conducted) that the test with DB Systemtechnik is posted online on the certificate. This is because the test is a test-report test from the perspective of the KTL and the SB because they failed to meet the standards set by the KTL and SB, and they are not actually used. Therefore, this part needs to be confirmed.

- Let me ask you about the test with DB Systemtechnik. Besides the one used in the case, did you have any previous tests related to overseas institutions?

  There have been many tests before. Previously, tests conducted with overseas institutions were conducted to verify that overseas technologies were manufactured and available to Korean standards when they wanted to be used domestically, based on the Korean Railway Operation Safety Act, called the Type Approval System. This was the task of taking a business trip to the place where the applicant is and using the facilities there to test and certify when the relevant national institution entrusts the KTL with the test. In other words, just as we are taking the European Technology Certification Test for use in Europe, foreign technology is the certification test for domestic advancement. In addition, tests such as SNCF-AEF and DB Systemtechnik, which are examples of this study, have been tested in conjunction with other institutions in Germany (which are different from today's labs).
- What is your unique experience with the DB Systemtechnik?

  From the user's point of view, in the case of DB Systemtechnik, it was often too late to receive the final report. Under the contract, the report came out within a month or two after the test, but it was tested in September and received the report the following year (over the year). Although this was the case, when the KTL saw the entire process of attending and testing (witnessed), it took a position to understand and accept each other's situation. It was because the test results could be used in Korea only if the test results were accepted after attending the meeting and recognizing them and because they had seen all of the procedures, there was no impatience with the test results and therefore could be understood even if the test report came out late. In the case of DB Systemtechnik, all the processes involved in the test were opened up and proceeded, and SNCF-AEF tended to place a little more restrictions (care more about security) when compared in this respect.
- What difficulties or experiences did you find in the nature of your organisation or cultural differences?

  In terms of cultural differences, there was a little difficulty in coordinating the European holiday schedule and adjusting business trips, or meeting schedules had a little difficulty. In the case of France, I think the engineers at the laboratory did a good job when they had to contact the engineers to proceed with the test process after being connected to the Eurailtest. I thought the case of DB Systemtechnik was a little conservative. Because the engineer had to solve both the sales and the technical aspects directly, when KTL contacted DB Systemtechnik directly, it felt a little conservative. When inquiring about a contract or requesting an answer, the response was relatively insignificant. Things began to go a little easier in the UK when I met and communicated with a consultant with the senior director of DB Systemtechnik. Attitudes have changed since the senior director began to proceed in direct connection with the laboratory technicians. As I experienced sincere responses, I felt conservative. However, once the first threshold was crossed, communication was accessible and straightforward. SNCF-AEF has felt softer and easier since the first contact, but there has been an experience in which the intermediate contacts have not been efficiently made.

- Why not both times with SNCF-AEF?

  For now, there is a price point. I chose SNCF for the first test because SB requested me to coordinate as requested. After the first test, when an estimate was received for the second test, the difference between the estimates on both sides (1.5 times) was so significant that the second laboratory was decided as DB Systemtechnik.

- What have brake pads been tested in both tests?

  From a technical standpoint, braking affects friction depending on the chemical composition of the product. The SNCF-AEF's tests determined to what level the product's performance (the materiality of the product: the number to which the component used affects braking force) was increased as a result of R&D and the DB Systemtechnik 's tests prepared three things and tried to test the first one and, depending on the results, tested one of the other two products, which resulted in non-useable results.

- What experience did you have when exchanging information or knowledge with each laboratory regarding knowledge and knowledge exchange?

  Overall, UIC operates a certification program. Both SNCF-AEF and DB Systemtechnik have experts designated by UIC who have participated in the process of creating these UIC certification programs. One of the main reasons for the overseas test was a lack of understanding of the overseas certification scheme, for example, as I tried to document what was written in the guidelines for preparing for UIC certification, I experienced some ambiguities and limitations in how to interpret it (which could be related to linguistic differences). These were things that could be learned and solved through communication with engineers during the test process. In this case, it can also be said that the ambiguity or difficulties that could arise from knowledge of the explicit have been overcome and resolved through the process of exchange of tacit knowledge. Anyway, since there was no way to solve the problem at home when it was discovered, it is important to be able to communicate with the experts stationed there through overseas laboratories, and in this sense, it can be said that KTL has become the leading testing agency among domestic institutions. Although there were no pre-supplied documents or guidebooks provided to the laboratory, the entire process was carried out based on the standard of 'UIC leaflet', and engineers were able to correct parts within the leaflet that could be interpreted differently. I was able to learn the problematic parts as I continued to get confirmation from time to time.

- Regarding the communication structure:
  The structure shown is correct. What's different from the first and second tests is 1) At first, SB, Professor Park Jaehwan and KTL communicated together, and then Professor Park Jaehwan contacted the Eurailtest and the test laboratory. In the second test on this part, after SB and KTL put their opinions together, KTL delivered them to Professor Park Jaehwan, and Professor Park Jaehwan contacted the laboratory. 2) In the first test, there was an intermediate institution Eurailtest before the laboratory, so the laboratory was contacted indirectly through this institution, but in the second test, the laboratory was contacted immediately without an intermediate institution. In addition to the first test, there was a problem with cost handling. There was a stage where, as a client, Eurailtest had to sign a contract directly on handling costs. At this time, after the contract, KTL entered the intermediate coordinator and intervened to play a role. For the second test, KTL signed directly with DB Systemtechnik. At this time, the client was KTL. From the perspective of KTL, the second was easier, and since the communication and knowledge transfer structure was ultimately the model that KTL wanted, it was a more purposeful test.
- Do you think it has something to do with the length of the communication system?
  From the perspective of a commissioned laboratory, when companies that have known and worked with it for a long time have asked for a test, efforts are made to make it easier on the technical side of the minor issues involved in the process. SB has long been involved in technology development, so it may be an example of an effort to reduce lead time. As an organisation that commissioned the test, so to speak, there was a process of investigating the laboratory to select one or two years before the test. In the case of SNCF-AEF and this test, consultants visited SNCF-AEF and Eurailtest in person, and KTL also visited SNCF-AEF in advance to find out the feasibility of the test, explain the R&D that KTL is conducting, and mention future test plans. Similarly, DB Systemtechnik laboratories have been continuously working with test workers for about a year or so to visit them in person and share opinions on the possibility of testing. Thus, both laboratories had previously held some period of business consultation and first began testing with SNCF-AEF. As mentioned in the organisational culture or system, DB Systemtechnik tended to be a little conservative compared to SNCF-AEF, so communication was not easy at first. When communication with the first connected person was a little difficult, luckily I met a higher-level test operation manager at the DB Systemtechnik Laboratory, and since then communication has been easier, and many problems have been solved. To sum up, even previously unrelated laboratories had some confirmation periods and, of course, the entry process was harder than other long-standing institutions, but it

was not noticeably difficult to proceed. Of course, we had questions about the uncertainty that came because we worked together for the first time, but after the test, confidence built up and there were no difficulties afterwards.

- Overall, how are these two tests evaluated?

  Some satisfaction can be assessed. I am also satisfied with the use of consultants and their relationship to produce test results. The two tests were more focused on creating R&D and test-related models than on cost or time-consuming tests, so it could be considered satisfactory because they thought they were close to the communication model they targeted, as was the case with DB Systemtechnik. It was also a qualitative approach to "making such efforts to advance abroad." In other words, even if the quantitative figures stipulated in the certification were not obtained, they were satisfied and found meaning in that they supported domestic technology development, conducted a test process to obtain overseas certification twice, established relationships with overseas institutions, identified models close to the desired communication model, and confirmed that the results were improving by repeating the tests. There is a strong willingness to establish relationships with these institutions and conduct tests afterwards.

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